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Bulletin of the Museum of Comparative Zoölogy
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VOL. XXIX. No. 1.

REPORTS ON THE DREDGING OPERATIONS OFF THE WEST COAST OF CENTRAL AMERICA TO THE GALAPAGOS, TO THE WEST COAST OF MEXICO, AND IN THE GULF OF CALIFORNIA, IN CHARGE OF ALEXANDER AGASSIZ, CARRIED ON BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," DURING 1891, LIEUT. COMMANDER Z. L. TANNER, U. S. N., COMMANDING.

XX.

THE FORAMINIFERA.

BY AXEL GOËS.

[Published by Permission of MARSHALL MCDONALD, U. S. Fish Commissioner.]

WITH NINE PLATES
AND CHART OF THE ROUTE OF THE ALBATROSS.

CAMBRIDGE, MASS., U. S. A.:
PRINTED FOR THE MUSEUM.
MARCH, 1896.

No. 1. — *Reports on the Dredging Operations off the West Coast of Central America to the Galapagos, to the West Coast of Mexico, and in the Gulf of California, in charge of* ALEXANDER AGASSIZ, *carried on by the U. S. Fish Commission Steamer "Albatross," during* 1891, Lieut. Commander Z. L. TANNER, U. S. N., Commanding.

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XX.

The Foraminifera.[1] By AXEL GOËS.

THE following notes are the result of an examination of bottom samples from 131 stations in the West Indian waters, and from 126 in the Pacific.

A look at the special description of the different bottoms and also at the bathymetrical list at the end of this Report shows that there is a sudden decrease of foraminiferal life below a depth of twelve hundred fathoms in these seas. It often happens that in greater depths, particularly in the Caribbean Sea, where the Globigerina deposits usually take immense proportions, the whole shell deposit of pelagic forms seems to be in a state of decay, probably owing to the chemical constitution of the deep water, with brownish brittle or half-broken shells, and such bottoms seem also to afford very scanty conditions for the development of this class of beings. Sometimes, also, where the Globigerina deposit is quite fresh, but present in too great abundance, it seems somewhat to prejudice their growth. We may suggest that a constant "snowing down" of dead pelagic forms may be injurious to many of these delicate organisms, leaving unimpaired only the stronger sand or débris builders, which may occur in such localities.

[1] To facilitate the comparison of the Foraminifera found on both sides of the Isthmus of Panama, Dr. Goës has included in this Report the results of an examnation of a series of selected samples of soundings collected by the U. S. C. S. S. "Blake" and by the U. S. F. C. S. "Albatross" in the Gulf of Mexico and in the Caribbean Sea. — A. AGASSIZ.

A closer comparison of the foraminiferal fauna on both sides of the Isthmus would have been important for completing our knowledge as to the relation of the faunas of the two seas. But besides that the Foraminifera offer but scanty leading features in this matter, on account of their more cosmopolite distribution than other classes, our material is at present too limited to allow us to make any general inferences on this matter. Besides, there is a blank in our knowledge about the fauna in the Pacific quarter in question living above five hundred fathoms, while from the Caribbean Sea there exists plenty of material from nine hundred to twenty fathoms of water. This may also be the reason why the bottom samples from the Pacific are quite devoid of shallow-water *Textulariæ, Clavulinæ, Cristellariæ, Nodosariæ, Planorbulinæ, Polystomellæ, Discorbinæ, Amphistiginæ, Miliolinæ, Vertebralinæ, Orbiculinæ*, etc.

Regarding the deep-water fauna of both seas (one thousand to fourteen hundred fathoms), one may with some degree of certainty infer that it is nearly common for the two. The few exceptions that may be apparent from our list of bathymetrical distribution may be accounted for by deficiency in the material searched.

Bottom Samples from Stations occupied in the Gulf of Mexico and the Caribbean Sea.

Hyd. 43. Lat. 18° N.; Long. 65° W.; about 8 miles N. to W. off St. Thomas (Virgin Islands).
1146 fathoms. Cor. sand, Globigerinæ (3 cub. centim.).
Globigerinæ + 0.

Hyd. 45. Lat. 17° 55′ N.; Long. 65° W.; 12 miles N. W. off Santa Cruz.
2501 fathoms. Cor. sand, Globiger. (8 c.c.).
Globigerinæ + few other pelagic species.

Hyd. 46. Lat. 17° 51′ N.; Long. 65° W.
2423 fathoms. Cor. sand, Globiger. (4 c.c.).
Globigerinæ + 0.

Hyd. 47. Lat. 17° 46′ N.; Long. 65° W.; 10 miles W. off Santa Cruz.
1482 fathoms. Cor. shells, Globiger. (10 c.c.).
Globigerinæ + 0.

Hyd. 48. Lat. 17° 37′ 30″ N.; Long. 65° 12′ 40″ W.; about 15 miles S. W. off Santa Cruz.
978 fathoms. Cor. ooze (6 c.c.).
Mostly pelagic species: Globigerinæ, Sphæroidina dehiscens Park. & Jones, Candeina nitida d'Orb., Pullenia obliqueloculata Park. & Jones, Pulvinulina Menardii, P. Micheliniana d'Orb.

A few bottom species are scantily represented, as Miliol. circularis BORNEM., M. tricarinata LMCK., Cassidulina subglobosa BRADY, Webbina clavata PARK. & JONES.

Hyd. 49. Lat. 17° 37′ N.; Long. 65° 15′ W.
928 fathoms. Globiger. ooze (7 c.c.).
Mostly pelagic forms as in the preceding, and Planorbul. Ungeriana, Pulvin. Schreibersi, Mil. sphæra, Mil. depressa D'ORB., Mil. circularis BORNEM.

Hyd. 51, 52, 53, 54, 55, 56, 57. Lat. about 17° N.; Long. about 65° W.; 20–40 miles S. W. off Santa Cruz.
933–2188 fathoms. Cor. ooze, Pteropodes, shells, Globiger. (93 c.c.). Globigerinæ and a few other pelagic species.

Hyd. 58. Lat. 17° 45′ N.; Long. 65° 35′ W., about 35 miles W. off Santa Cruz.
1345 fathoms. Globiger. ooze (5 c.c.).
Rhabdammina abyssorum SARS, R. discreta BR., Hyperammina elongata BR., Crithionina granum GOËS, Webbina clavata PARK. & JONES, Ammodiscus incertus D'ORB., Trochammina lituiformis BR., Hormosina ovicula BR., Cyclammina cancellata NORMAN (large), Haplophragm. latidorsatum BORNEM., Verneuilina propinqua BR. (scarce), Gaudryina rugosa D'ORB., Cristell. rotulata LMCK. f. cultrata, Nod. pauperata, Mil. depressa, D'ORB.

Hyd. 59. Lat. 17° 42′ N.; Long. 65° 39′ W.; about 38 miles W. by S. off Santa Cruz.
789 fathoms. Globiger. ooze (15 c.c.).
Pelagic specimens of common forms, Haplophr. agglutinans, Gaudryina rugosa D'ORB., Cassidulina subglobosa BR., Uvigerina Auberiana, 1 sp., Nod. lævigata D'ORB., Lagena marginata WALK., 1 sp., Planorbulina Ungeriana D'ORB., 1 sp., Plan. Wüllerstorfi SCHWAG., Pulvin. elegans D'ORB., Pulv. pauperata PARK. & JONES, Mil. (Sigmoilina) celata COSTA.

Hyd. 60. Lat. 17° 39′ N.; Long. 65° 44′ W.; 40 miles W. S. W. off Santa Cruz.
578 fathoms. Cor. sand, Globiger. (11 c.c.).
Gaudryina rugosa D'ORB., 1 sp., Pulv. pauperata PARK. & JONES, 1 sp., Mil. tricarinata D'ORB., 1 sp.

Hyd. 62. Lat. 17° 32′ N.; Long. 65° 52′ W.
2017 fathoms. Cor. sand, Pterop., Globiger. (14 c.c.).
Globigerinæ + 0.

Hyd. 65, 66, 67. Lat. 16° N.; Long. about 64° W.
2069–2312 fathoms. Cor. sand, shell, Globiger. (25 c.c.).
Globigerinæ + 0.

Hyd. 68. Lat. 16° N.; Long. 64° W.; about 30 miles N. W. off Aves Island.
1920 fathoms. Globiger. ooze (12 c.c.).
Cyclammina pusilla BR., 1 sp., Lagena marginata WALK., 1 sp., Nodos. obliqua LIN., 1 sp., Pulvin. pauperata PARK. & JONES, 1 sp.

Hyd. 69, 78. Lat. 14°–15° N.; Long. 63°–64° W.; off Aves Island.
1060-871 fathoms. Cor. sand, Globiger. ooze (20 c.c).
Globigerinæ + 0.

Hyd. 88. Lat. 12° 29′ N.; Long. 62° 38′ W.; 80 miles W. by N. from St. Vincent.
1630 fathoms. Mud w. black specks, Globiger. (5 c.c.).
Hyperammina elongata Br., Webbina clavata Park. & Jones, Trochammina lituiformis, 1 sp., Cyclammina pusilla, Reophax nodulosus Br., Sphæroidina dehiscens Park. & Jones, 2 sp., Planorbulina Ungeriana d'Orb., Wüllerstorfi Schwag., Cristellaria rotulata Lmck. Diverse common pelagic species.

Hyd. 79. Lat. 14° 20′ N.; Long. 63° W.; about 130 miles W. by N. from St. Lucia.
821 fathoms. Sand, shell, Globiger. (6 c.c.).
Ammodiscus incertus d'Orb., Haplophragm. latidorsatum Bornem., 1 sp., Pulvin. elegans d'Orb., 3 sp., Pulv. pauperata Park. & Jones, 2 sp., Miliol. simplex, Mil. depressa d'Orb., Mil. (Sigmoilina) sigmoidea Br., 1 sp.

Hyd. 80. Lat. 13° 56′ N.; Long. 63° W.; about 108 miles S. S. E. from St. Lucia.
684 fathoms. Gray mud, Globiger. (5 c.c.).
Webbina clavata Park. & Jones, 1 sp., Haplophragm. latidorsatum Bornem., 1 sp., Cyclammina cancellata Norm., 1 sp., Nodos. soluta Rss., 1 sp., Rotalina Soldanii d'Orb., 1 sp.

Hyd. 82. Lat. 13° 29′ N.; Long. 62° 42′ W.; about 83 miles W. by N. from St. Vincent.
1051 fathoms. Mud w. black specks, sand, Globiger. (20 c.c.).
Hormosina ovicula Br., 1 sp., Cyclammina cancellata Norm., 2 sp., Haplophragm. latidorsatum Bornem., 1 sp.; Reophax nodulosus Br., 1 sp., Pulv. pauperata Park. & Jones, 1 sp., Rotalina Soldanii (small), Mil. depressa d'Orb., Mil. circularis Bornem.

Hyd. 86. Lat. 12° 58′ N.; Long. 62° 48′ W.; about 75 miles N. W. from Grenada.
1635 fathoms. Brown mud w. black specks, Globiger. (5 c.c.).
Haplophragmium helicoideum Goës, Cyclammina pusilla, Trochammina trullisata Br., 1 sp.

Hyd. 114. Lat. 13° 48′ N.; Long. 63° 20′ W.; about 120 miles W. N. W. from St. Vincent.
652 fathoms. Brown ooze; decayed Globiger. 3 (c.c.).
0.

Hyd. 120. Lat. 16° N.; Long. 65° 56′ W.; about 120 miles S. from Porto Rico.
2492 fathoms. Grey mud, Globiger. (5 c.c.).
0.

Hyd. 121. Lat. 16° 36′ N.; Long. 66° 41′ W.; about 22 miles S. off Porto Rico.
2501 fathoms. Chocol.-colored mud, Globiger. ooze (5 c.c.).
0.

Hyd. 122. Lat. 16° 35′; Long. 68° W.; about 32 miles S. S. W. from Mona Island.
2458 fathoms. Chocol.-colored ooze, Globiger. (6 c.c.).
0.

Hyd. 123, 124. Lat. 15° N.; Long. 67° W.
2616–2747 fathoms. Chocol.-colored ooze, Globiger. (10 c.c.).
0.

Hyd. 131. Lat. 12° N.; Long. 66° 16′ W., about 15 miles N. W. off Orchila Island.
1806 fathoms. Chocol.-colored Globiger. ooze (5 c.c.).
Chilostomella ovoides REUSS, 1 sp., Nod. obliqua LIN., 1 sp., Mil. depressa D'ORB., 1 sp.

Hyd. 133. N. Lat. 11° 23′ N.; Long. 66° 19′ W.; about 20 S. off Orchila.
533 fathoms. Gray mud, Globiger. (6 c.c.).
Cyclammina pusilla BR., 1 sp., Haplophragm. latidorsatum BORNEM., f. nitidum, 1 sp., Gaudryina pupoides, Clavulina communis D'ORB., 1 sp., Planorbulina lobatula WALK., 2 sp., Planorb. Ungeriana D'ORB. var., Bulim. ellipsoides COSTA, Nodos (Lingulina) carinata, Nod. communis D'ORB., 1 sp., Cristell. rotulata LMCK., Lagena marginata WALK., 1 sp., Rotalina Soldanii, Mil. depressa D'ORB. Scattered pelagic species.

Hyd. 135. Lat. 11° N.; Long. 66° 30′ W.; about 37 miles S. W. from Orchila.
239 fathoms. Green mud, sand.
Hyperammina friabilis, Reophax sabulosus BR., 1 sp., Clavulina Soldanii PARK. & JONES, Reophax procerus GOËS, Textularia Trochus D'ORB., Discorbina valvulata D'ORB., 1 sp., Orbiculina adunca FICHT. & MOLL., Orbitolites marginalis LMCK.

Hyd. 175. Lat. 17° 44′ N.; Long. 72° 35′ W.; about 55 miles S. from S. Domingo.
1594 fathoms. Brown mud, Globiger. (3 c.c.).
0.

Hyd. 176. Lat. 17° 28′ N.; Long. 72° 36′ W.; about 50 miles S. W. from S. E. point of Porto Rico.
1946 fathoms. Yellow mud, sand, Globiger.
, Only pelagic species: Globigerinæ, Pulvin. Menardii, Pulv. crassa, Caudeina nitida D'ORB., Sphæroid. dehiscens, Pullenia obliqueloculata PARK. & JONES.

Hyd. 177, 178, 179, 180, 181, 182. S. off St. Domingo.
2369–2490 fathoms. Brown mud, Globiger. (20 c.c.).
Globigerinæ + 0.

Hyd. 187. Lat. 18° N.; Long. 74° 31′ W.; 20 miles S. S. W. off C. Tiburon, S. Domingo.

894 fathoms. Sand, mud, shells (6 c.c.)

Cyclammina pusilla Br., 1 sp., Haplophragm. latidorsatum Bornem., 1 sp., Pulvin. pauperata Park. & Jones, 1 sp., Mil. seminulum Lin., 1 sp., Mil. sphæra d'Orb.

Hyd. 188. Lat. 17° 51′ N.; Long. 74° 36′ W.; about 35 miles S. S. W. from C. Tiburon, S. Domingo.

894 fathoms. Yellow mud, shells, Globiger. (25 c.c.).

Lagena marginata Walk., 1 sp., Mil. depressa d'Orb.

Hyd. 189. Lat 17° 42′ N.; Long. 74° 40′ W.; about 30 miles S. W. from C. Tiburon, S. Domingo.

803 fathoms. Brown mud, Globiger. (8 c.c.).

Trochammina trullisata Br., 1 sp.; Haplophragm. latidorsatum Bornem., 1 sp.; Rotalina Soldanii d'Orb., 1 sp., Mil. seminulum Lin., Mil. depressa, Mil. sphæra d'Orb. Pelagic species.

Hyd. 205. Lat. 19° 40′; Long. 74° 42′ W.; about 45 miles S. W. from C. Maysi, Cuba.

1923 fathoms. Gray mud, sand, Globiger. (3 c.c.).

0.

Hyd. 209. Lat. 19° 47′ N.; Long. 75° 41′ W.; about 20 miles S. E. off S. Jago, Cuba.

1425 fathoms. Brown mud, shells, sand (4 c.c.).

Ammodiscus incertus d'Orb., Haplophragm. latidorsatum Bornem., Haplophr. helicoideum Goës.

Hyd. 214. Lat. 19°; Long. 75° 21′ W.; about 50 miles S. from Cuba.

1768 fathoms. Yell. mud, shell, Globiger. (3 c.c.).

0.

Hyd. 215. Lat. 18° 54′ N.; Long. 75° 16′ W.; about 60 miles S. from Cuba.

1486 fathoms. Yell. mud, shells, Globiger. (3 c.c.).

Trochammina lituiformis, Br., 1 sp.; Planorb. Wüllerstorfi Schwag., 1 sp.

Hyd. 219. Lat. 18° 22′ N.; Long. 75° 41′ W.; about 75 miles S. from Cuba.

646 fathoms. Broken shells (4 c.c.).

0.

Hyd. 314. Lat. 16° 54′ N.; Long. 75° 33′ W.; about 72 miles S. W. from Morant Pt., Jamaica.

1012 fathoms. Yell. mud, sand, Globiger. (20 c.c.).

Various pelagic species, Haplophragm. helicoideum Goës, 1 sp., Haplophr. latidorsatum Bornem., 1 sp.; Cyclammina pusilla, Cassidulina subglobosa Br., Pulvin. pauperata Park. & Jones, Mil. celata Costa, 1 sp., Mil. depressa, Mil. sphæra d'Orb., 1 sp.

Hyd. 315, 316, 317, 319, 320, 321; about 15° N. Lat.; about 75° W. Long.
45–190 miles S. and S. S. E. from Morant Pt., Jamaica.
1250–2315 fathoms. Yell. mud, Globiger. (15 c.c.).
Globigerinæ + 0.

Hyd. 368. Lat. 10° 14′ N.; Long. 80° 30′ W.; about 120 miles N. N. W. from Aspinwall.
1853 fathoms. Brown mud, decayed Globiger.
0.

Hyd. 371. Lat. 11° 20′ N.; Long. 80° 42′ W.; about 123 miles N. W. from Aspinwall.
1832 fathoms. Brown mud, Globiger.
Reophax nodulosus Br., 1 sp., Nodos. communis d'Orb., 1 sp., Pulvin. pauperata Park. & Jones, 1 sp.; Mil. depressa d'Orb., 2 sp.

Hyd. 373. Lat. 12° N.; Long. 81° W.; about 45 miles S. E. from St. Andrew's-Island.
1736 fathoms. Brown mud, Globiger. (5 c.c.).
0.

Hyd. 388. Lat. 14° 48′ N.; Long. 80° 23′ W.; about 100 miles N. N. E. from Old Providence Island.
1069 fathoms. Yell. mud, Globiger. (10 c.c.).
Hormosina ovicula Br., Gaudryina rugosa d'Orb., Pulvin. pauperata Park. & Jones, Pulv. elegans, 1 sp., Mil. sphæra d'Orb., Mil. circularis Bornem., Mil. sigmoidea Br., Mil. seminulum Lin., 1 sp. Various pelagic species.

Hyd. 391. Lat. 15° N.; Long. 80° 23′ W.; about 108 miles N. N. E. from Old Providence.
756 fathoms. Yell. Globiger. ooze, coral (10 c.c.).
Trochammina lituiformis Br., 1 sp., Cassidulina subglobosa Br., Pulv. elegans d'Orb., Planorbulina Wüllerstorfi Schwag., 1 sp., Mil. sigmoidea Br., Mil. circularis Bornem., Mil. depressa d'Orb. Pelagic species.

Hyd. 386, 390, 400, 402, 403, 404, 405, 410. Lat. 15°–19° N.; Long. 80° 84′ W.
735–3169 fathoms. Mud, Globiger. ooze (30 c.c.).
Globigerinæ, pelagic species + 0.

Hyd. 399. Lat. 17° 25′ N.; Long. 82° W.; about 93 miles E. from Swane Island.
920 fathoms. Yell. Globiger. ooze (5 c.c.).
Globigerinæ, Pulv. elegans, 1 sp.; Mil. depressa d'Orb., Mil. circularis Bornem.

Hyd. 419. Lat. 23° 48′ N.; Long. 84° W.; about 120 miles S. W. from Marquesas Islands.
1356 fathoms. Yell. Globiger. ooze (3 c.c.).
Haplophragm. helicoideum Goës, Haplophragm. latidorsatum var. nitidum, Pulvin. elegans, 1 sp., Mil. sphæra, Mil. depressa d'Orb. Pelagic species.

Hyd. 421, 450, 451, 452. Lat. 22° N.; Long. 84° 85′ W.; about 6–25 miles N. W. from St. Antonio, Cuba.
476–1238 fathoms. Globiger. ooze, Pterop. (15 c.c.).
Pelagic species + 0.

Hyd. 513, 514. Lat. 22° 11′ W.; Long. 85° W.; about 10 miles N. from St. Antonio.
953–986 fathoms. Yellow Globiger. ooze, cor. (4 c.c.).
Webbina clavata PARK. & JONES, 1 sp. Trochammina lituiformis BR., Pulvinulina elegans PARK. & JONES, 1 sp.

Hyd. 515. Lat. 22° N.; Long. 85° W.; 7 miles N. W. off C. St. Antonio.
769 fathoms. Yell. Globiger. ooze (4 c.c.).
Ammodiscus incertus D'ORB., Trocham. lituiformis, Tr. conglobata, Tr. ringens BR., Haplophragm. latidorsatum D'ORB., 1 sp., Mil. simplex, Mil. depressa D'ORB., Mil. circularis BORNEM. Pelagic species.

Stat. 2117. Lat. 15° 24′ N.; Long. 63° 31′ W.; about 120 miles W. from Dominica.
683 fathoms. Yell. Globiger ooze (42 c.c.).
Globiger. + pelagic species.

Stat. 2135. Lat. 19° 55′ N.; Long. 75° 47′ W.; S. E. off S. Jago, Cuba.
262 fathoms. Cor. shells.
Clavulina Soldanii PARK. & JONES, Reophax procenes GOËS, Textularia trochus D'ORB., Miliol. sphæra D'ORB.

Stat. 2140. Lat. 17° 36′ N.; Long. 76° 46′ W.; about 23 miles S. S. E. from Port Royal, Jamaica.
966 fathoms. Sand (10 c.c.).
Reophax nodulosus BR., 1 sp., Ammodiscus incertus D'ORB., 1 sp., Trochammina proteus KARR., Troch. lituiformis BR., 1 sp.; Hormosina (monile) Carpenteri BR., 1 sp., Cyclamnina pusilla BR., Haplophragmium globigeriniformis PARK. & JONES, H. latidorsatum BORNEM., H. obsoletum GOËS, Gaudryina rugosa D'ORB., 1 sp., Planorbulina Ungeriana D'ORB., Pulvin. pauperata PARK. & JONES, Pulv. elegans D'ORB., Mil. seminulum D'ORB., 1 sp., M. circularis BORNEM., 1 sp., M. depressa D'ORB. Pelagic species.

Stat. 2144, 2145, 2146. Lat. 9° 30′ N.; Long. 79° 50′.
896–25 fathoms. Green mud, shells, Globiger. (20 c.c.).
0.

Stat. 2150. Lat. 13° 34′ N.; Long. 81° 15′ W.; about 15 miles N. by E. off Old Providence.
382 fathoms. Cor., Globiger. ooze.
Ammod. incertus D'ORB., Trocham. proteus, lituiformis, trullisata, Cyclammina pusilla, Hormosina Carpenteri BR., Haplophragm. helicoideum GOËS, Hapl. globigeriniformis PARK. & JONES, Hapl. compressum GOËS.

Stat. 2150.

Globiger. ooze (40 c.c.).

Clavulina communis, parisiensis, Gaudryina rugosa, pupoides D'ORB., scabra BR., Textularia luculenta BR., concava BR. (KARR.), 1 sp., Bigenerina pennatula BATSCH, 1 sp., Cassidulina subglobosa BR., Lagena marginata WALK., Cristell. rotulata LMCK., calcar LIN., Vagin. glabra D'ORB., 1 sp., Nodos. communis D'ORB., 1 sp., N. soluta RSS., pauperata, pyrula, hispida D'ORB., obliqua LIN., raphanistrum LIN., lævigata D'ORB., 1 sp., Planorbulina Ungeriana D'ORB., Pulvinulina pauperata PARK. & JONES, elegans D'ORB., Mil. irregularis D'ORB., simplex, depressa D'ORB., circularis BORNEM., (Sigmoilina) celata COSTA. Pelagic species.

Stat. 2151. Lat. 15° 28′ N.; Long. 80° 36′ W.; about 130 miles N. N. E. from Old Providence.

653 fathoms. Corals, Globiger. ooze.

Cristallaria italica, DEFR.

Stat. 2315. Lat. 24° 26′ N.; Long. 81° 48′ W.; about 11 miles S. S. E. from Key West.

159 fathoms. Coarse sand, shells (40 c.c.).

Clavulina parisiensis var. bigerinoides GOËS, Text. trochus D'ORB., Amphistegina vulgaris D'ORB., Mil. (rugosa SCHLUMB.) contorta ? D'ORB.

Stat. 2318. Lat. 24° 25′ N.; Long. 81° 46′ W.; about 10 miles S. S. E. off Key West.

45 fathoms. Cor. (6 c.c.).

Clavulina parisiensis D'ORB., Vaginul. linearis MONTAG., Amphistegina vulgaris D'ORB.; Orbiculina adunca FICHT. & MOLL., 1 sp.

Stat. 2320, 2322. Lat. 23° 10′ N.; Long. 82° 17′ W.; off Havana.

115–130 fathoms. Cor. (10 c.c.).

Polytrema miniaceum, LIN.

Stat. 2339. Lat. 23° 10′ N.; Long. 82° 20′ W.; off Havana.

191 fathoms. Cor. (10 c.c.).

Reophax procerus GOËS, Text. trochus D'ORB., Amphistegina vulgaris D'ORB.

Stat. 2352. Lat. 22° 35′ N.; Long. 84° 23′ W.; about 18 miles N. W. from west end of Cuba.

463 fathoms. Coral (20 c.c.).

Hyperammina elongata, BR., Reophax armatus GOËS, Trochammina trullisata, 1 sp., lituiformis BR., Webbina clavata PARK. & JONES, Ammodiscus incertus D'ORB., Cyclammina cancellata NORM., Haplophrag. latidorsatum BORNEM., compressum GOËS, Clavulina communis D'ORB., Gaudryina scabra BR., rugosa D'ORB., Cassidulina subglobosa BR., Nodos. communis D'ORB., soluta RSS., obliqua LIN., Crist. rotulata LMCK., Planorbul. lobatula WALK., Ungeriana, Pulv. elegans D'ORB., Schreibersi D'ORB., Nonionina depressula WALK., 1 sp., Rotalina Soldanii D'ORB., 1 sp., Cornuspira foliacea PHIL., Mil.

simplex, sphæra, depressa D'ORB., seminulum LIN., circularis BORNEM., Sigmoïlina sigmoidea BR. Pelagic species.

Stat. 2354. Lat. 20° 59′ N.; Long. 86° 23′ W.; about 30 miles off Cozumel Island.

130 fathoms. Cor. (20 c.c.).

Text. trochus D'ORB., Crist. rotulata LMCK., vortex FICHT. & MOLL., Nodos. communis D'ORB., 1 sp.

Stat. 2355. Lat. 20° 56′ N.; Long. 86° 27′ W.; about 47 miles E. by S. to S. off the middle mouth of Mississippi River.

399 fathoms. Globiger. ooze (10 c.c.).

Trochammina conglobata, trullisata BORNEM., Cyclammina pusilla BR., Webbina clavata PARK. & JONES, Haplophragm. compressum GOËS, latidorsatum MONTF., Reophax scorpiurus BR., Cassidulina subglobosa D'ORB., Clavulina communis, parisiensis D'ORB., Gaudryina scabra BR., Text. trochus LMCK., Bigenerina capreolus D'ORB., pennatula BATSCH, Cristellaria rotulata D'ORB., Nodos. hispida D'ORB., 1 sp., Planorbulina Ungeriana D'ORB., lobatula WALK., Ariminensis D'ORB., Robertsoniana BR., Pulvin. pauperata PARK. & JONES, elegans D'ORB., Mil. insignis BR., depressa D'ORB., circularis BORNEM., (Sigmoïlina) sigmoidea BR., celata COSTA.

Stat. 2358. Lat. 20° 19′ N.; Long. 87° W.; off west shore of Cozumel Island.

222 fathoms. Cor. (12 c.c.).

Webbina clavata PARK. & JONES, 1 sp., Ammodisc. incertus, Nod. communis D'ORB., Vaginul. linearis MONTAG., 1 sp., Pulv. repanda FICHT. & MOLL., pauperata PARK. & JONES, Rotalina Soldanii, Mil. sphæra D'ORB., (Sigmoïlina) sigmoidea BR., Orbiculina adunca FICHT. & MOLL., Orbitolites marginalis LMCK.

Stat. 2361, 2363. Lat. 22° N.; Long. 87° W.; about 35 miles N. N. E. from Cape Catoche, Yucatan.

21–25 fathoms. Cor. sand (20 c.c.).

Orbitolites marginalis LMCK. + 0.

Stat. 2369, 2370, 2371. Lat. 29° 17′ N.; Long. 85° 31 W.; about 26 miles S. W. from Cape San Blas, Florida.

26 fathoms. Sand, shells (80 c.c.).

Rheophax scorpiurus MONTF., Clavulina communis D'ORB., Pulvinulina repanda FICHT. & MOLL., Cristell. calcar LIN., Lingulina carinata, 1 sp., Amphistegina vulgaris D'ORB., Mil. seminulum LIN., contorta? D'ORB., Orbiculina adunca FICHT. & MOLL.

Stat. 3377. Lat. 29° N.; Long. 88° W.; 75 miles S. by W. from Fort Morgan, Alabama.

210 fathoms. Gray mud (20 c.c.).

Rhabdammina abyssorum M. SARS, Reophax scorpiurus MONTF., nodulosus BR., latidorsatum BORNEM., compressum GOËS, Ammodiscus incertus D'ORB., Webbina clavata PARK. & JONES, Cyclammina cancellata NORM., Clavulina

communis var. eocæna GÜMB., parisiensis D'ORB., Soldanii PARK. & JONES, Verneuilina triquetra MÜNST., Valvulina conica PARK. & JONES, Textularia rugosa? RSS., Bulimina ellipsoides COSTA, Virgul. squamosa, Uviger. pygmæa D'ORB., Cristell. rotulata LMCK., marginata D'ORB., gibba D'ORB., aculeata (d'Orb.) BR., Nodos. obliqua LIN., pyrula, hispida D'ORB., Frondic. alata, Lingulina carinata D'ORB., 1 sp., Lagena marginata WALK., 2 sp., Planorb. Ungeriana D'ORB., Pulvin. pauperata PARK. & JONES, Cornuspira foliacea PHIL., Discorb. valvulata D'ORB., Miliol. seminulum LIN., tricarinata, depressa D'ORB., Spiroloculina robusta BR. Pelagic species.

Stat. 2378. Lat. 29° 14′ N.; Long. 88 W.; about 63 miles S. by W. from Fort Morgan.

68 fathoms. Gray mud (10 c.c.).

Clavulina Soldanii PARK. & JONES, communis var. cocæna GÜMB., Cristell. rotulata, LMCK., Nodos. obliqua LIN., Boueana D'ORB., Miliol. simplex D'ORB.

Stat. 2379. Lat. 28° N.; Long. 87° 42′ W.; about 105 miles S. E. by S. from the mouths of Mississippi River.

1467 fathoms. Globiger. ooze (3 c.c.).

Hormosina globulifera BR., Pulvinul. pauperata PARK. & JONES.

Stat. 2381. Lat. 28° N.; Long. 87° 56′ W.; about 90 miles S. E. by S. from the middle mouth of Mississippi.

1330 fathoms. Light brown mud. Globiger. (10 c.c.).

Hyperam. ramosa BR., elongata BR., Haplophragm. helicoideum GOËS, latidorsatum BORNEM., Cyclammina cancellata NORM., 1 sp., Ammodiscus incertus D'ORB., Hormosina ovicula BR., Clavulina communis var. cocæna GÜMB., Clavul. communis D'ORB., Chilostomella ovoides RSS., Cristell. rotulata LMCK., 1 sp., Crist. aculeata (D'ORB.) BR. var., Mil. seminulum LIN., simplex D'ORB., depressa D'ORB.

Stat. 2383. Lat. 28° 32′ N.; Long. 88° W.; about 70 miles S. S. E. from the middle mouth of Mississippi.

1181 fathoms. Brown, green mud (75 c.c.).

Hyperammina ramosa, elongata BR., Haplophragm. latidorsatum BORNEM., helicoideum GOËS, Ammodiscus incertus D'ORB., Trochammina galeata BR., Cyclammina cancellata NORM., Webbina clavata PARK. & JONES, Hormosina ovicula BR., Clavulina communis D'ORB., Verneuilina propinqua, Cassidulina subglobosa BR., Cristell. rotulata LMCK. -cultrata, Crist. subarcuatula MONTAG., Nodos. pauperata D'ORB., obliqua LIN., Pulvin. elegans D'ORB., pauperata PARK. & JONES, Miliol. depressa D'ORB.

Stat. 2384. Lat. 28° 45′ N.; Long. 88° 15′ W.; about 58 miles S. S. E. from the middle mouth of Mississippi.

940 fathoms. Brown, gray mud, Rhabdammina (15 c.c.).

Astrorhiza vermiformis GOËS, Rhabdammina abyssorum M. SARS, linearis BR., Crithionina pisum GOËS, Hyperammina ramosa BR., Webbina clavata PARK. & JONES, Ammodiscus incertus D'ORB., Cristell. rotul.-cultrata MONTF., Pulvin. pauperata PARK. & JONES, Mil. depressa D'ORB.

Stat. 2385. Lat. 28° 51′ N.; Long. 88° 18′ W.; about 48 E. by S. from the same point as above.

730 fathoms. Gray mud, Rhabdam. (12 c.c.).

Rhabdammina abyssorum M. Sars, Hyperammina ramosa Br., Webbina clavata Park. & Jones, Ammodiscus incertus d'Orb., Valvulina conica (small), Pulvin. pauperata Park. & Jones, Miliol. sphæra, depressa d'Orb.

Stat. 2389. Lat. 29° N.; Long. 87° 56′ W.; about 50 miles S. S. E. from Fort Morgan.

27 fathoms. Gray sand, shells (40 c.c.).

0.

Stat. 2392. Lat. 28° 47′ N.; Long. 87° 27′ W.; about 95 miles S. from Fort Pickens.

724 fathoms. Brown, gray mud, Globiger. (15 c.c.).

Hyperammina elongata, Reophax nodulosus Br., 1 sp., Haplophragm. latidorsatum var. nitidum Goës, lituolinoideum Goës, Trochammina ringens Br., Bulimina aculeata d'Orb., Nod. soluta Rss., Lagena formosa Schwag., marginata Walk., 1 sp., Planorbul. Ungeriana d'Orb. Pelagic species: Hastigerina, broken.

Stat. 2394. Lat. 28° 38′ N.; Long. 87° W.; about 110 miles S. from Fort Pickens.

420 fathoms. Green mud (25 c.c.).

Rhabdammina abyssorum M. Sars, Hyperam. ramosa, elongata Br., Haplophragm. compressum Goës, latidorsatum Bornem., lituolinoideum Goës, Reophax nodulosus, dentaliniformis Br., Reoph. turbo Goës, Ammodiscus incertus d'Orb., Trocham. ringens, lituiformis Br., Cyclammina cancellata Norm., Webbina clavata Park. & Jones, Hormosina Carpenteri, Verneuilina propinqua, scabra Br., Gaudryina rugosa d'Orb., Crist. rotulata Lmck., calcar Lin., variabilis Rss., Nodos. radicula Lin., pauperata Park. & Jones, lævigata d'Orb., soluta Rss., obliqua Lin., Planorbulina Ungeriana, Pulvin. elegans d'Orb., pauperata Park. & Jones, Rotalina Soldanii d'Orb.

Stat. 2395. Lat. 28° 36′ N.; 86° 50′ W.; about 113 miles E. by S. from Fort Pickens.

347 fathoms. Gray mud (22 c.c.).

Nearly the same species as those of the preceding.

Stat. 2397, 2398. Lat. 28° 43′ N.; Long. 86° 30′ W.; about 108 miles S. S. E. from Fort Pickens.

227–280 fathoms. Gray mud, Globiger. (30 c.c.).

Rhabdammina abyssorum M. Sars, Cyclammina cancellata Norm., Haplophragmium compressum Goës, Cristell. rotulata Lmck., Nodos. raphanistrum, obliqua Lin., pauperata, hispida d'Orb., Pulvin. pauperata Park. & Jones, 2 sp., Clavul. communis, 4 sp., parisiensis d'Orb., 1 sp. Various pelagic species.

Stat. 2399. Lat. 28° 44′ N.; Long. 86° 18′ W.

Stat. 2400. Lat. 28° 4′ N.; Long. 86° W.

About 113–120 miles S. S. E. from Fort Pickens.

196–169 fathoms. Gray mud, decayed Globiger. (78 c.c.).

Rhabdammina abyssorum M. SARS, Hyperammina ramosa, elongata, 4 sp., Jaculella acuta BR., 1 sp., Cyclammina cancellata NORM., Hormosina ovicula BR., Haplophragmium latidorsatum BORNEM., compressum GOËS, Reophax nodulosus, pilulifer BR., Valvulina conica PARK. & JONES, Clavulina communis D'ORB., communis var. cocæna GÜMB., parisiensis D'ORB., rudis COSTA, Verneuilina triquetra MÜNST. (plenty), propinqua BR., Gaudryina pupoides D'ORB., Textul. rugosa RSS., agglutinans D'ORB., Cristellaria rotulata LMCK., (cultrata, stenostegica,) aculeata (D'ORB.) BR. var. italica DEFR., marginata D'ORB., Nodos. pauperata D'ORB., soluta RSS., pyrula, hispida D'ORB., obliqua LIN., Lingulina carinata D'ORB., Frondicularia alata D'ORB., Planorbulina Ungeriana, Ariminensis, Pulv. Schreibersi D'ORB., auricula FICHT. & MOLL.

Stat. 2404. Lat. 28° 44′ N.; Long. 85° 16′ W.; 63 miles S. from Cape San Blas, Florida.

Stat. 2405. Nearly the same place as the preceding.

Stat. 2406. About 65 miles S. E. by S. from Cape San Blas.

Stat. 2409. Lat. 27° N.; Long. 83° 21′ W.; about 52 miles W. from Florida.

Stat. 2410. Lat. 26° 47′ N.; Long. 83° 25′ W.; 72 miles W. by S. from Charlotte Bay, Florida.

Stat. 2413. Lat. 26° N.; Long. 82° 57′ W.; about 64 miles S. W. from Charlotte Bay, Florida.

24–60 fathoms. Gray sand, broken corals (50 c.c.).

Amphistegina Lessoni D'ORB., Orbitalites marginalis LMCK.

Stat. 2639, 2640, 2641, 2647. Lat. 86° 25′ N.; Long. 80° W.; about 510 miles off Florida Keys and Cape.

56–80 fathoms. Cor. sand (50 c.c.).

Scanty Globiger. + 0.

Stat. 2643. Lat. 25° 25′ N.; Long. 79° 55′ W.; about 20 miles W. off south part of Florida.

211 fathoms. Gray sand.

Rhabdammina abyssorum M. SARS, discreta BR. var. friabilis, Nodosaria soluta RSS., 1 sp.

Stat. 2655. Lat. 27° 22′ N.; Long. 78° W.; about 32 miles N. N. W. off west point of Little Abaco, Bahama.

338 fathoms. Gray sand.

Clavulina Soldanii PARK. & JONES (large), Text. trochus D'ORB.

Bottom Samples from Stations occupied in the Pacific.

Diverse samples from 92 Hydrographic Stations ranged between Nos. 43 and 2570 in "Albatross" record, the contents of each varying in amount from $\frac{1}{10}$ to 1 cubic centimeter (seldom to 5 cubic centimeters), have yielded but scarce specimens of young and undeveloped Foraminifera, as of common Globigerinæ and other pelagic forms.

H. Stat. 2610. Lat. 5° 29′ N.; Long. 86° 49′ W.
1009 fathoms. Globiger. ooze (3 c.c.).
Common pelagic species, Trochammina pauciloculata Br., 1 sp.

H. Stat. 2613. Lat. 3° 50′ N.; Long. 81° 44′ W.
1181 fathoms. Brown Globiger. ooze (5 c.c.).
Common pelagic species.

H. Stat. 2618. Lat. 7° 27′ N.; Long. 78° 46′ W.
1708 fathoms. Gray Globiger. ooze (2 c.c.).
Scanty pelagic species.

H. Stat. 2627. Lat. 0° 6′ N.; Long. 82° 45′ W.
1832 fathoms. Yellow green ooze (6 c.c.).
Reophax pilulifer Br., Bulimina ellipsoides Costa, Uvigerina pygmæa var. aculeata, Auberiana d'Orb., Chilostomella ovoides Rss., Nodos. communis d'Orb., Lagena gracillima Seg. Several common pelagic species.

Stat. 3344. Lat. 47° 20′ N.; Long. 125°.
831 fathoms. Green mud (3 c.c.)
Chilostomella ovoides Rss. (large), Virgulina squamosa d'Orb.

Stat. 3345, 3346. Lat. about 45° 35′ N.; Long. about 124° 33′.
759–786 fathoms. Green mud (2 c.c.).
0.

Stat. 3353. Lat. 7° 6′ N.; Long. 80° 34′ W.; E. off Mariata Point.
695 fathoms. Green mud (15 c.c.).
Haplophragm. canariense d'Orb., Textularia sagittula var. cuneiformis d'Orb. Bolivina punctata d'Orb., Bulimina ellipsoides Costa, Uvigerina pygmæa, Auberiana d'Orb., Nodos. raphanus Lin. (1 small sp.), Lag. marginata Walk., Chilostom. ovoides Rss., Planorbulina Wüllerstorfi Schwag. (poor), Rotalina Soldanii d'Orb. (poor), Planorb. mundula Park. & Jones. Pelagic species, as Globiger. dubia Egger, etc.

Stat. 3357. Lat. 6° 35′ N.; Long. 81° 44′ W.; about 30 miles S. from Coiba Island.
782 fathoms. Gray green sand (15 c.c.).
Astrorhiza angularis Br., Reophax dentaliniformis Br., Uvigerina Auberiana d'Orb., Chilostomella ovoides Rss., Lagena gracillima Seg., pelagic species; all scanty and in decay.

Stat. 3358. Lat. 6° 30′ N.; Long. 81° 44′ W.
557 fathoms. Green sand (7 c.c.).
Thurammina erinacea GOËS, pelagic species (poor).

Stat. 3360. Lat. 6° 17′ N.; Long. 82° 5′ W.; 60 miles S. W. from Pt. Mariato.
1672 fathoms. Fine dark green sand (3 c.c.).
0.

Stat. 3361. Lat. 6° 10′ N.; Long. 83° 6′ W.; about 100 miles S. S. W. from P. Mariato.
1471 fathoms. Green ooze (10 c.c.).
Thurammina erinacea GOËS, Clavulina communis D'ORB., 1 sp., Nodos. pauperata D'OBB. Pelagic species.

Stat. 3364, 3363, 3366. About Lat. 5° 40′ N.; Long. 86° 20′ W.; about 50 miles E. off Cocos Island.
902, 978, 1067 fathoms. White and yellow Globiger. ooze, half decayed (resp. 28 and 10 c.c.).
Reophax distans BR., Webbina clavata PARK. & JONES, 1 sp., Trochammina trullisata BR., 1 sp.; Clavulina communis, Gaudryina rugosa, 1 sp., Uvigerina pygmæa var. aculeata D'ORB., Auberiana, Virgulina squamosa D'ORB., Chilostomella ovoides RSS., Nodosar. pauperata D'ORB., Lag. marginata, Planorbul. Wüllerstorfi SCHWAG., Miliol. depressa D'ORB. Several pelagic species in bad condition.

Stat. 3371, 3372. Lat. about 5° N.; Long. ab. 86° 30′ W.; E. and S. E. from Cocos Island.
770–761 fathoms. Gray Globiger. ooze (resp. 15 and 20 c.c.).
Thurammina erinacea GOËS, Gaudryina rugosa D'ORB., 1 sp., Bulimena ellipsoides COSTA, Chilost. ovoides RSS., Cassid. subglobosa BR., Nodos. lævigata D'ORB. Several pelagic species. Pulvin. elegans D'ORB., pauperata PARK. & JONES, Planorb. grosserugosa? GÜMB., Wüllerstorfi SCHWAG.

Stat. 3374. Lat. 2° 35′ N.; Long 83° 53′ W.; 180 miles S. E. from Cocos Isl.
1823 fathoms. Green Globiger. ooze (20 c.c.).
Pelagic species; Bulimina ellipsoides COSTA.

Stat. 3375. Lat. 2° 34′ N.; Long. 82° 29′ West.; 120 miles N. W. from Galera Point.
1201 fathoms. Gray Globiger. ooze (100 c.c.).
Astrorhiza granulosa BR., Rhizammina algæformis BR., Rhabdammina abyssorum SARS, Hyperammina elongata BR., Bathysiphon filiformis, Bath. rufus DE FOLIN, Haplophr. latidorsatum BORNEM., globigeriniformis PARK. & JONES, Reophax dentaliniformis, nodulosus, bacillaris, distans BR., Webbina clavata PARK. & JONES, Trochammina trullisata, pauciloculata, Cyclammina pusilla, Hormosina globulifera BR., Clavulina communis, Gaudryina pupoides D'ORB., Textul. sagittula var. cuneiformis D'ORB., Uvigerina Auberiana var. lævis.

Ehrenbergina serrata var. trigona Goës, Bolivina punctata d'Orb., Cristellaria rotulata Lmck., italica Defr., Nodos. lævigata d'Orb., soluta Rss., pyrula d'Orb., Lagena marginata Walk., Orbignyana Seg., var. elongata, L. gracillima Seg., distoma Park. & Jones, distensa Goës, marginata var. staphyllæria Schwag., Pulvinulina elegans d'Orb., pauperata Park. & Jones, Planorbulina Wüllerstorfi Schwag., grosserugosa? Gümb. Miliolina depressa var. serrata Br., Cornuspira foliacea Phil. Several pelagic species of Globigerina, Pullenia, Sphæroidina Park. & Jones, and Pulvinulina.

Stat. 3376. Lat. 3° 9′ N.; Long. 82° 8′ W.; 30 miles E. N. E. from Galera Point.

1132 fathoms. Gray Globiger. ooze (500–600 c.c.).

Crithionina lens Goës, rugosa Goës, Bathysiphon rufus de Folin, Reophax bacillaris, 1 sp., dentaliniformis, 1 sp., difflugiformis Br., Ammodiscus incertus d'Orb., Hormosina globulifera Br., 2 sp., Haplophragm. latidorsatum Bornem., 2 sp., Clavulina communis (plenty), Gaudryina rugosa d'Orb., Cristell. rotulata Lmck., gibba d'Orb., 1 sp., Vaginul. glabra, Nodos. lævigata, pauperata, communis d'Orb., soluta Rss., obliqua Lin., 1 sp., Lagena lævis Montag. (few), Orbignyana var. elongata, gracillima Seg., Bulimina ellipsoides Costa, Virgulina subsquamosa Egger, Boliv. punctata d'Orb., Planorbul. grosserugosa? Gümb., Wüllerstorfi Schwag., Pulvin. elegans d'Orb., pauperata, Miliolina depressa d'Orb., Mil. depressa var. serrata Br. Pelagic species.

Stat. 3382. Lat. 6° 21′ N.; Long. 80° 41′ W.; 35 miles S. E. from Pt. Mariato.

Stat. 3383. Lat. 7° 21′ N.; Long. 79° 2′ W.; 40 miles E. from Cape Mala.

1793–1832 fathoms. Green mud + Globiger. (resp. 8 and 5 c.c.).

Thurammina erinacea Goës, Bolivina punctata, Pulvinul. elegans d'Orb. Pelagic species few.

Stat. 3392. Lat. 7° 5′ N.; Long. 79° 40′ W.; 65 miles S. from Panama.

1270 fathoms. Rhabdammina bottom (about 1000 c.c.).

Rhabdammina abyssorum var. irregularis Carp. abundant.

Stat. 3395. Lat. 7° 30′ N.; Long. 78° 39′ W.; 60 miles E. from Cape Mala.

730 fathoms. Rocks (7 c.c.).

Thurammina erinacea Goës, Uvigerina pygmæa var. aculeata, Auberiana d'Orb., Bulimina ellipsoides Costa, Virgulina subdepressa Br., Boliv. punctata, plicata d'Orb., Cristellaria rotulata Lmck., Rhabdagonium tricarinatum Rss., Pulvinul. elegans d'Orb. Pelagic species.

Stat. 3399. Lat. 1° 7′ N.; Long. 8° 4′ W.; 35 miles W. N. W. from Galera Point.

1740 fathoms. Brown green ooze, decayed Globiger. (50 c.c.).

Neusina Agassizi Goës, Placopsilina bulla, Reophax distans Br., Uvigerina pygmæa, Nodosaria pauperata d'Orb., Lagena formosa Schwag., 1 sp. Pelagic nearly decayed specimens.

Stat. 3400. Lat. 0° 36′ S.; Long. 86° 46′ W.; 95 miles E. from Chatham Island.

1322 fathoms. Light gray Globiger. ooze (20 c.c.).

Bulimina ellipsoides COSTA, Ehrenbergina serrata var. trigona GOËS, Chilostomella ovoides Rss., Nodosar. communis D'ORB., Lagena distensa GOËS, Pulvinulina elegans, Miliolina sphæra D'ORB. Pelagic species.

Stat. 3407. Lat. 0° 4′ S.; Long. 90° 24′ W.; E. N. E. off James Island.

885 fathoms. Globiger. ooze (600 c.c.).

Astrorhiza angulata BR., 1 sp., Crithionina rugosa GOËS, lens GOËS, Bathysiphon filiformis M. SARS, Hyperammina ramosa, elongata, Jaculella obtusa BR., Ammodiscus incertus D'ORB., tenuis BR., Haplophragmium helicoideum GOËS, Reophax dentaliniformis BR., Reophax insectus GOËS, Gaudryina rugosa D'ORB., G. chilostoma Rss., Bulimina ellipsoides COSTA, Polymorphina ovata D'ORB., 1 sp., Cristellaria rotulata LMCK., Nodosar. lævigata D'ORB., obliqua LIN., soluta Rss., Lagena marginata WALK. (large), seminiformis SCHWAG., Pulvinul. elegans D'ORB., pauperata PARK. & JONES, Planorbul. Wüllerstorfi SCHWAG., Miliol. sphæra, irregularis D'ORB., circularis BORNEM., depressa D'ORB. (plenty), obesa Rss. Several pelagic species.

Stat. 3414. Lat. 10° 14′ N.; Long. 96° 28′ W.; about 300 miles S. S. E. from Acapulco.

2232 fathoms. Green mud (7 c.c.).

Neusina Agassizi GOËS.

Stat. 3415. Lat. 14° 46′ N.; Long. 98° 40′ W.; 95 miles S. E. from Acapulco.

1879 fathoms. Brown mud, Globiger. ooze.

Neusina Agassizi GOËS, Rhizammina algæformis BR., Crithionina rugosa GOËS, Thurammina erinacea GOËS, Haplophragm. latidorsatum var. umbilicatum GOËS, Hapl. helicoideum GOËS, Ammodiscus tenuis BR., Reophax difflugiformis BR., armatus GOËS, Hormosina globulifera BR. Few pelagic species.

Stat. 3418. Lat. 16° 33′ N.; Long. 99° 52′ W.; S. off Acapulco.

660 fathoms. Brown sand w. black specks (10 c.c.).

Rhabdammina abyssorum (small), Bathysiphon filiformis, Saccammina sphærica M. SARS, Webbina clavata PARK. & JONES, Cyclammina cancellata NORM., Haplophragm. fontinense TERQU., latidorsatum BORNEM. (plenty), Reophax dentaliniformis BR., Ammodiscus incertus D'ORB. (large), Gaudryina scabra BR., 2 sp., Cristell. rotulata LMCK. (in bad state), Planorbulina Wüllerstorfi SCHWAG., Pulvin. elegans D'ORB.

Stat. 3419. Lat. 16° 34′ N.; Long. 100° 3′ W.; off Acapulco.

772 fathoms. Green mud w. black specks.

Rhabdammina abyssorum M. SARS (large), Astrorhiza furcata GOËS, Bathysiphon filiformis M. SARS, Bath. filif. var. arenaceus GOËS, Saccammina sphæ-

rica M. Sars, Crithionina lens Goës, Placopsilina bulla Br., Verrucina rudis Goës, Haplophragm. latidorsatum var. umbilicatum Goës, fontinense Terqu., globigeriniforme Park. & Jones, Reophax insectus Goës, Webbina clavata Park. & Jones, Ammodiscus incertus d'Orb., tenuis Br. (large, plenty), Cyclammina pusilla Br., cancellata Norm., Clavulina communis d'Orb., Verneuilina propinqua, Gaudryina scabra Br., Bulim. ellipsoides Costa, pyrula d'Orb., Cristell. rotulata Lmck., Chilostomella ovoides Rss. (large), Pulvinul. elegans d'Orb., Planorb. Wüllerstorfi Schwag., Rupertia stabilis Wall.

Stat. 3429. Lat. 22° 30′ N.; Long. 107° 1′ W.; 40 miles W. S. W. from Mazatlan.

919 fathoms. Green mud, Globiger. ooze.

Thurammina erinacea Goës, Planorb. mundula Park. & Jones, Pulvin. elegans d'Orb.. Pelagic species few.

Stat. 3431. Lat. 23° 59′ N.; Long. 108° 40′ W.; 35 miles S. W. from Altata.

995 fathoms. Light brown mud, Globiger. (41 c.c.).

Astrorhiza tenuis Goës, Rhabdammina abyssorum (large), Bathysiphon filiformis M. Sars (large), Thurammina erinacea Goës, Saccammina sphærica M. Sars, Haplophragm. latidorsatum Bornem., Hapl. latid. v. umbilicatum Goës, Haplophragm. fontinense Terqu., Reophax scorpiurus Mtfrt. (small), R. insectus Goës, Cyclamm. cancellata Norm. (large), Webbina clavata Park. & Jones, Ammodiscus incertus d'Orb., tenuis Br. (large), Clavulina communis v. lævis, Verneuil. pusilla Goës, Gaudryina scabra Br., Uvigerina pygmæa v. aculeata d'Orb., Auberiana d'Orb., Bul. ellipsoides Costa, Bul. inflata Seg., Virg. squamosa, Cristellaria rotulata Lmck., Nodos. pyrula d'Orb., Lag. aspera Rss., marginata v. staphyllearea Schwag., Planorb. Wüllerstorfi Schwag., mundula Park. & Jones, Pulvin. elegans (plenty), Rotalina Soldanii, Miliolina depressa d'Orb. Some pelagic species.

Stat. 3433. Lat. 25° 26′ N.; Long. 109° 48′ W.; 30 miles N. W. from Topolobampo.

1218 fathoms. Brown mud w. black specks (8 c.c.).

Thurammina erinacea Goës, Haplophragm. globigeriniformis Park. & Jones, Trocham. trullisata Br., 1 sp., Uviger. pygmæa v. aculeata, 1 sp., Bulimina pyrula d'Orb., 1 sp., Virg. squamosa, Boliv. punctata d'Orb., 1 sp., Chilostomella ovoides Rss., Planorb. mundula Park. & Jones, Rotal. Soldanii 1 sp., Mil. tricarinata d'Orb., etc. Diverse pelagic species.

ASTRORHIZA Sandahl.

A. granulosa Brady.

A. granulosa Br., 1884, Challeng. Rep., IX. p. 234, Pl. XX. Figs. 14–23.

A few of this not well distinct species have been met with at 2° 34′ Lat. N.; 82° 29′ Long. W. The color is lighter than in the typical form.

Two specimens of a very small growth (1.5 mm.), probably belonging to *A. granulosa*, have been met with in the Caribbean Sea at 1,630 fathoms. The shell wall is very brittle, being constructed of sand and sponge needles, etc.

Pacific. 1201 fathoms; scarce.

A. crassatina Brady.

A. crassatina Br. (1881), 1884, Challeng. Rep., IX. p. 233, Pl. XX. Figs. 1–9.

To this species I assign with some doubt a good lot of stout, rough, fusiform specimens of the same shape as the typical ones, represented by Brady; but the tube channel is more even and not varicously dilatated as in that. The walls are thick, loosely cemented of shell débris, mud, and sand, grayish or ash-colored; length 10–15 mm.; diam. 2–3 mm.

Pacific. 885 fathoms.

A. angulosa Brady.

A. angulosa Br. (1881), 1884, Challeng. Rep., IX. p. 234, Pl. XX. Figs. 10–13.

A not very well distinguished form; it is sometimes nearly impossible to distinguish it from more loosely agglutinating forms of *Rhabdammina abyssorum* with lost arms. Diam. 2-3 mm.

Pacific. A few specimens from 885 fathoms off St. James Island.

A. furcata, n.

Plate I. Figs. 4, 5.

Usually flat-convex, with three arms, one longer and two shorter, rapidly tapering to the apertural ends; the wall constructed of mud and fine sand grains; color dark gray. May even be ranked in the allied genus *Pelosina* Br. Length about 5 mm.

Fig. 4 lateral; Fig. 5, marginal aspect.

Pacific. 772 fathoms, off Acapulco; scarce.

A. tenuis, n.

Plate I. Figs. 6–8.

More or less slender cylindrical or fusiformed tubes, usually tapering to the ends, with constricted apertures. Tube-channel smooth, with faint traces of spurious septa. Wall loosely cemented of coarse sand, light grayish, comparatively thick. Length 5–10 mm.; diam. 1–1.5 mm.

Fig. 6, a broken specimen; Fig. 7, transverse section of the same; Fig. 8, the tube laid open, showing spurious septation.

Pacific. 995 fathoms; scarce.

A. vermiformis, n.

Plate I. Fig. 9.

Tube more or less tortuously bent, usually constructed of dark grayish mud; the apertures somewhat constricted at the more or less tapering ends. Length about 10–13 mm. The surface of dried specimens is often provided with annular fine crevices.

Caribbean Sea. A few specimens from 940 fathoms.

RHIZAMMINA Brady.

R. indivisa Brady.

R. indivisa Brady, 1884, Challeng. Rep., IX. p. 277, Plate XXIX. Figs. 5–7.

Stout tubes of this form have been met with. They differ from *Astrorhiza vermiformis* only in having the test constructed principally of Foraminifera tests instead of mud. The reason why Brady has assigned this form to Rhizammina is not quite clear.

Pacific. 1201 fathoms; scarce.

Gulf of Mexico. 1345–211 fathoms; scarce.

R. algæformis Brady.

Rhizammina algæformis Br. (1879), 1884, Challeng. Rep., IX. p. 274, Pl. XXVIII. Figs. 1–11.

A single but monstrous tuft of this singular Foraminifer has been met with in the Pacific. The height of the tubes exceeds sometimes 38 mm.

Pacific. 1879 fathoms.

RHABDAMMINA M. Sars.

R. abyssorum Sars.

R. abyssorum M. Sars, 1868, Det Dyriske Livs Udbredning i Havets Dybder, Christiania Videnskab. Selskab. Forhandl., 1868, p. 248.
R. abyssorum Br., 1884, Challeng. Rep., IX. p. 266, Pl. XXI. Figs. 1–8, 10–13.
R. abyssorum Goës, 1893, Synops. Arct. & Scand. Rec. Mar. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 19, Pl. IV. Figs. 67, 68.

The typical forms from Norwegian seas, with long, narrow, and even arms, are more seldom met with; often the arms are thicker and shorter, sometimes varicously uneven.

Pacific. 2° 34′ Lat. N.; 82° 29′ Long. W.; 1201 fathoms.
Caribbean Sea. 100–900 fathoms; not plenty.

Allied Forms:—

1. **R. discreta** Brady. Plate I. Figs. 13, 14.

R. discreta Br. (1881), 1884, Challeng. Rep., IX. p. 268, Pl. XXII. Figs. 7–10.

Arms more or less varicous by a spurious segmentation, or annulated by closely arranged circular impressions. Single arms are mostly met with, complete specimens with 3–4 arms but seldom occurring; the channel of the arms provided with slight impressions; their length and thickness very variable. The wall is usually firmly agglutinated and hard, but occasionally more brittle specimens are met with, constructed by fine whitish sand.

Fig. 13, small brittle form; Fig. 14, same, constructed of sand and sponge spicules.

Pacific. 772 fathoms.
Caribbean Sea. 200–1345 fathoms.
The whitish more brittle form, Caribbean Sea. 211 fathoms.

2. **R. linearis** Brady.

R. linearis Br., Challeng. Rep., IX. p. 269, Pl. XXII. Figs. 1–6.

Very little distinguishable from the preceding but for its globular or ovoid chamber near the middle of the tube, which is provided with a spurious segmentation like that of the preceding form. Both are to be considered as retarded or emaciated forms of *abyssorum*.

Caribbean Sea. 211–940 fathoms; scarce.

3. **R. irregularis** Carp.

R. irregularis Carp., 1881, The Microscope, p. 562.
R. irregularis Br., 1884, Chall. Rep., IX. p. 267, Pl. XXI. Fig. 9.

Arms often dichotomous branching, at their outset often slightly arcuated. Attains not seldom 1–1½ inches in length.

Pacific. 995–1270 fathoms.

At this depth, in 71° 5′ Lat. N., 79° 40′ Long. W., found in greatest abundance, affording one of the most prominent constituents of the bottom.

HYPERAMMINA Brady.

H. elongata Brady.

H. elongata Br., 1878, Ret. & Radiol. Rhizop. Arct. Exped. 1875–76, Ann. Mag. Nat. Hist., ser. 5, I. p. 433 (partly).

H. elongata Br., 1884, Challeng. Rep., IX. p. 257, Pl. XXIII. Figs. 4, 7–10.

H. elongata Goës, 1893, Arct. & Scandin. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 17, Pl. IV. Figs. 55–58.

The smooth North Atlantic form has very rarely been met with; the shell wall usually being more coarse.

Pacific. 885–1201 fathoms; scarce.

Caribbean Sea. 169–1630 fathoms; scarce.

Allied Form:—

H. friabilis Brady.

H. elongata Br., 1878, Retic. & Radiol. Rhizop. Arct. Exped. 1875–76, Ann. Mag. Nat. Hist., ser. 5, I. p. 433, Pl. XX. Fig. 2.

H. elongata Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 142, Pl. XII. Figs. 426–428, ? 429.

H. friabilis Br., 1884, Chall. Rep., IX. p. 258, Pl. XXIII. Figs. 1–3, 5, 6.

H. friabilis Goës, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 17, Pl. IV. Fig. 59.

Is not very distinct from the type, particularly the more shiny specimens.

Caribbean Sea. 239 fathoms; scarce.

H. ramosa Brady.

H. ramosa Br., 1879, Rhizop. Challeng. Exped.; Qu. Journ. Microsc. Sc. (n. s.), XIX. p. 33, Pl. III. Figs. 14, 15.

H. ramosa Br., 1884, Challeng. Rep., IX. p. 261, Pl. XXIII. Figs. 15–19.

H. ramosa Goës, 1893, Arct. & Scandin. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 18, Pl. IV. Figs. 61, 62.

Our form is somewhat stouter and more firmly built than specimens from the North Atlantic. Whole samples with spared primordial chamber are very seldom met with.

Pacific. 885–1201 fathoms.

Caribbean Sea. 169–1830 fathoms; scarce.

JACULELLA Brady.

J. acuta Brady.

J. acuta Br., 1879, Ret. Rhizop. Chall. Exp.; Qu. Journ. Micr. Sci. (n. s.), XIX. p. 35, Pl. III. Figs. 12, 13.
J. acuta Br., 1884, Challeng. Rep., IX. p. 255, Pl. XXII. Figs. 14–18.

A single but stout specimen has been met with from the Gulf of Mexico.
Gulf of Mexico. 169 fathoms; rare.

J. obtusa Brady.

J. obtusa Br. (1882), 1884, Challeng. Rep., IX. p. 256, Pl. XXII. Figs. 19–22.
J. obtusa Goës, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 20, Pl. IV. Figs. 87–89; Pl. V. Figs. 90, 91.

It is not without hesitation that I refer a lot of thin, slender, dark gray, and rough, straight, or somewhat bent at one end, very tapering tubes, to the above form of Brady; but in all other respects except the black gray color of the agglutinated materials they agree with the type. As usual the primordial portion is wanting, and a tube open at both ends only remains. Its length is somewhat more than 10 mm.

Pacific. 885 fathoms; not plenty.

BATHYSIPHON M. Sars.

B. filiformis M. Sars.

B. filiformis M. Sars, Christiania Vidensk. Selsk. Forhandl., 1871, p. 251.
B. filiformis Br., 1884, Challeng. Rep., IX. p. 248, Pl. XXVI. Figs. 15–20.
B. filiformis Goës, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 16, Pl. III. Figs. 39–41.

Very stout, thick-walled specimens occur in "Albatross" collections. The bore of the tube is in such specimens narrower than in the more thin-shelled ones, and the rings of growth or the spurious septation very faint. The apertures are often somewhat constricted on the tapering ends. Sometimes one of the tube ends seems to be closed by a cribrous lamina. Attains a length of 25 mm. Forms with a more rough and sandy surface (Pl. I. Figs. 11, 12) occur also, although some doubt may arise about their ranging with the species on record; the circular impressions on this form are nearly obsolete.

Pacific. 660–1201 fathoms; not scarce.

Allied Form: —

B. rufus de Folin. Plate I. Fig. 10.

B. rufum de Folin, 1887, Les Bathysiphons, Acts Soc. Lin. Bordeaux, XL. p. 283, Pl. VII. Fig. 8.

Usually very slender, with needle-formed origin, gradually increasing in thickness; the annular impressions often very conspicuous; test generally smooth, sometimes glossy, of yellow or reddish brown color, like that of a smooth *Hyperammina elongata*. May be considered as a pygmy form of the type. Length about 10 mm. A stout straight specimen, somewhat more than an inch in length and one mm. in diameter, found off Acapulco in 772 fathoms, may with some doubt also be ranked with this variety.

Pacific. 772–1201 fathoms.

Caribbean Sea. 1345 fathoms; rare.

CRITHIONINA Goës.

C. pisum, n.

Plate II. Figs. 1. 2.

Usually globular or subglobular, with comparatively smooth surface, often here and there provided with irregular impressions; wall thick, obsoletely subcavernous; traces of septa very obsolete; texture very loose, chalky, homogenous; color whitish or gray. Diameter 1–3 mm.

Gulf of Mexico. 940 fathoms; rare.

C. rugosa, n.

Plate II. Figs. 3, 4.

Subglobular, with coarsely tuberculated surface; wall thick, obsoletely cavernous, the chamber somewhat irregular, showing faint traces of subdivision; color gray or whitish; the consistency of the shell is usually loose, the texture being finely arenaceous, with a large portion of shell débris. It seems to be closely allied to *C. mamilla* Goës, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 15, Pl. III. Figs. 34–36, which is smaller and affixed. Diameter 1–2 mm.

Pacific. 885–1879 fathoms; not plenty.

C. lens, n.

Plate II. Figs. 5-8.

Flattened, orbicular or oblong, often somewhat irregular in its contour; its cavity is more or less regularly subdivided in radial chamberlets or tubes, originating in an oval or globular undivided central chamber. When this is very large, the subdivided part looks as if constituting the shell wall itself. Sometimes the central cavity is reduced or obsolete. Surface relatively smooth, texture fine and loose; color light ash-gray. Diameter 2–4 mm.

Fig. 5, marginal; Fig. 6, lateral aspect; Figs. 7, 8, the inner laid open from both sides.

Pacific. 772–1122 fathoms.

C. granum var. subsimplex, n.

Conf. *C. granum* Goës, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 15, Pl. III. Figs. 28–33.

Resembles in shape the type, but the walls are thin and the subdividing lamina of the cavity very much reduced, sometimes nearly obsolete.

Caribbean Sea. 1345 fathoms; rare.

PLACOPSILINA d'Orb.

P. bulla Brady.

P. bulla Br. (1881), 1884, Chall. Rep., IX. p. 313, Pl. XXXV. Figs. 16, 17.
P. bulla Goës, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 28, Pl. VI. Figs. 211–215.

Has been met with on greater depths of the Pacific sparingly. The bottom of the hemispheres is often cribrous.

Pacific. 772–1740 fathoms, mostly adherent to Rhabdammina.

VERRUCINA Goës.

V. rudis Goës.

Plate I. Figs. 15, 16.

Affixed; of irregular ovoid shape; surface rough, of agglutinated sand; the cavity divided into a few more or less regular chambers, which have their outlet in an irregular aperture in the centre of the somewhat sunken top.

Pacific. 772 fathoms; usually affixed to Rhabdammina.

Fig. 15, apertural side, showing the excavation and the irregular aperture; Fig. 16, side view.

THURAMMINA Brady.

T. papillata Brady.

T. papillata Br., 1879, Ret. Rhizop. Chall. Exp., Qu. Journ. Microsc. Sci. (n. s.), XIX. p. 45, Pl. V. Figs. 4–8.
T. papillata Br., 1884, Chall. Rep., IX. p. 321, Pl. XXXVI. Figs. 7–18.

A single specimen only has been met with.

Caribbean Sea. 724 fathoms; rare.

T. erinacea n.

Plate II. Figs. 9, 10.

It is with some doubt that I range this form in the above genus of Brady, although it agrees in some respects with *T. papillata*, except in the obsolete state of its orifices, which are not plainly visible in our form. Its surface is somewhat wrinkled, tuberculated, and beset with short, closely arranged spines; sometimes the spines are more scattered, and very produced in length. The shape is usually globular, seldom ovoid; sometimes the test is provided with a short neck or shaft. Its color is usually gray-yellowish, sometimes whitish, with black specks, some of which may be orifices. The wall is more or less thin. The diameter seldom reaches beyond 0.25 mm.

Pacific. 555–1879 fathoms; not rare.

SACCAMMINA M. Sars.

S. sphærica Sars.

S. sphærica M. Sars, 1868, Det dyriske Livs Udbred. i Havets dybder., Christiania Vidensk. Selsk. Hdl., 1868, p. 248.
S. sphærica Br., 1884, Chall. Rep., IX. p. 253, Pl. XVIII. Figs. 11–17.
S. sphærica Goës, 1893, Arct. & Scandin. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 13, Pl. III. Figs. 16–18.

Stout specimens and in a good lot of samples have been met with, not differing in any respect from the North Atlantic form.

Pacific. 660–995 fathoms; not scarce.

REOPHAX Mtfrt.

R. scorpiurus Mtfrt.

R. scorpiurus Mtfrt., 1808, Conchol. Système, I. p. 330.
Lituolina scorpiurus Goës, 1882, Retic. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 136, Pl. XI. Figs. 406–409.
R. scorpiurus Br., 1884, Chall. Rep., IX. p. 291, Pl. XXX. Figs. 12–17.
R. scorpiurus Goës, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 24, Pl. V. Figs. 158–163, Pl. VI. Figs. 164–169.

The specimens brought home by the "Albatross" are but few, and not quite typical.

Pacific. 995 fathoms; pygmy, with very constricted sutures; scarce.

Caribbean Sea. 210 fathoms.

ALLIED FORMS:—

1. **R. dentaliniformis** BRADY.

R. dentaliniformis BR., Chall. Rep., IX. p. 293, Pl. XXX. Figs. 21, 22.

Variable in size and thickness, sometimes with more constricted sutures and segments more or less inflated. A slender pigmy form is often met with. The neck of the segments usually produced. A larger variety, with only two or three oblong cylindrical segments, is also met with.

Pacific. 885–1201 fathoms; less rare.

Caribbean Sea. 420 fathoms; scarce.

The larger two-chambered variety from Pacific, 1201 fathoms.

2. **R. bacillaris** BRADY.

R. bacillaris BR. (1881), 1884, Chall. Rep., IX. p. 293, Pl. XXX. Figs. 23, 24.

A more ill defined form than what may be inferred from the figures of Brady, the chief difference from the preceding being its shorter, somewhat globular segments.

Pacific. 1132–1201 fathoms; rare.

3. **R. pilulifer** BRADY.

R. pilulifera BR., 1884, Chall. Rep., IX. p. 292, Pl. XXX. Figs. 18–20.
R. pilulifer GOËS, 1893, Arct. & Scandin. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 25, Pl. VI. Figs. 176–180.

A few samples have been met with.

Pacific. 1800 fathoms.

Caribbean Sea. 100 fathoms; scarce.

4. **R. distans** BRADY.

R. distans BR. (1881), 1884, Chall. Rep., IX. p. 296, Pl. XXXI. Figs. 18–22.

The form met with by the "Albatross" has the segments more globiform than that exhibited in Brady's illustrations. Usually only samples, with 2–3 coherent segments, are met with. Color dirty brown, sometimes ash-gray.

Pacific. 772–1740 fathoms; not very scarce.

5. **R. nodulosus** BRADY.

Only the slender, antennula-like brown form has been met with. It differs somewhat from the North Atlantic form, but agrees well with the form represented by Brady, Chall. Rep., IX. p. 294, Pl. XXXI. Figs. 3, 4.

Pacific. 1201 fathoms; not plenty.

Gulf of Mexico. 280–1832 fathoms; not plenty.

R. procerus Goës.

Plate III. Figs. 1 to 5.

Lituolina fœdissima Goës, 1882, Retic. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 138, Pl. XII. Figs. 415–418.

Clavulina procera Goës, 1889, Dimorphism, Sv. Vet. Ak. Bihang, XV. 4, No. 2, p. 9, Pl. II. Fig. 17.

R. procerus Goës, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 27, Pl. VIII. Figs. 413–417.

A good lot of this conspicuous form has been met with, but only in the Caribbean Sea. Its valvulate aperture resembles that of a Clavulina.

Fig. 1, large specimen; Fig. 2, oral aspect; Fig. 3, cut through the prime segment; Fig. 4, pygmy form; Fig. 5, its oral aspect.

Caribbean Sea. 100–300 fathoms.

R. insectus, n.

Plate III. Figs. 6, 7.

Irregular conic, the more mature segments subglobular, with incised sutures; aperture often slightly limbated or protruding; wall not very thick, built of middle coarse sand, its surface rough; light brown or grayish; length 5–8 mm., the last segment 1.5–2 mm. in diameter. Its nearest ally seems to be *R. sabulosus*, which it somewhat resembles in shape, but is not provided with such thick and loosely cemented walls, and misses also the rusty colored inside layer that is a striking feature of the latter.

Pacific. 772–995 fathoms; not scarce.

R. sabulosus Brady.

Lituolina scorpiurus var. *ammophila* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 137, Pl. XII. Figs. 410–414.

R. sabulosa Br. (1882), 1884, Chall. Rep., IX. p. 298, Plate XXXII. Figs. 5, 6; Goës, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 27, Pl. VI. Figs. 199–202.

A few samples of middle size have occurred.

Caribbean Sea. 239–262 fathoms.

R. difflugiformis Brady.

R. difflugiformis Br. (1879), 1884, Chall Rep., IX. p. 289, Pl. XXX. Figs. 1–5.

R. difflugiformis Goës, 1893, Arct. & Scand. Foramf., p. 26, Pl. VI. Figs. 196–198.

Has been found only very rarely at a few stations in the Pacific.

Pacific. 1132–1879 fathoms; scarce.

R. armatus, n.

Plate I. Fig. 1.

The growth of the test is nearly the same as that of *R. distans*, but the segments are provided with 3–6 more or less produced spines or tubes; sometimes it seems as if some one of those tubes were in connection with side chambers, so that a construction somewhat like a Ramulina is originated. Shell wall thin, light brown, built up by finest sand and sponge spicules, often partly covered with white dust; the surface is often sparingly prickly by sponge needles. The scarcity of the supply has not allowed a closer examination and analysis of this peculiar form.

Pacific. 1879 fathoms; one sample only.

Caribbean Sea. 463 fathoms; very scarce.

R. turbo, n.

Plate I. Figs. 2, 3.

Chambers conical trochiform, marginated, the margin on one side somewhat crenulated, the necks slender. One-chambered specimens only open at their two ends have been met with; test thin, firmly constructed of finest sand; surface nearly smooth.

Caribbean Sea. 347–420 fathoms; scarce.

HAPLOPHRAGMIUM.

H. latidorsatum Bornem.

Nonionina latidorsata Bornem., 1855, Septarienthon Hermsdorf, Zeitschr. deut. geol. Gesellsch., VII. p. 339, Pl. XVI. Fig. 4.

Lituolina irregularis var. Goës, 1882, Ret. Rhizop. Carib. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 139, Pl. XII. Figs. 419, 420.

H. latidorsatum Br., 1884, Challeng. Rep., IX. p. 307, Pl. XXXIV. Figs. 7–10, 14.

H. latidorsatum Goës, 1891, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 21, Pl. V. Figs. 102–120.

Usually both sides are without umbilicus, but sometimes provided with narrow ones. The number of segments is generally 4 or 5, in large specimens increasing to 7. The aperture is extremely narrow, and sometimes substituted by a row of pores. In many instances the surface is comparatively smooth. It seems to attain a greater development on the western side of the Isthmus.

Pacific. 660–1879 fathoms; not scarce, particularly at 600–700 fathoms.

Caribbean Sea. 196–1425 fathoms; not scarce.

ALLIED FORM:—

H. nitidum Goës. Plate III. Figs. 8, 9.

H. latidorsatum var. *nitidum* Goës, 1891, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 21, Pl. V. Figs. 121–123.

Smooth and glossy, usually narrow umbilicated; number of segments, 4; color brown, reddish, or yellow; always only half the size of the type.

Caribbean Sea. 530–1830 fathoms; not plenty.

H. canariense d'Orb.

Nonionina canariensis d'Orb., 1839, For. Canaries, p. 128, Pl. II. Figs. 33, 34.
H. canariense Br., 1884, Chall. Rep., IX. p. 310, Pl. XXXV. Figs. 1–5.
H. canariense Goës, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 20, Pl. V. Figs. 92–101.

Comparatively stout specimens of this form have been found from off Acapulco and at other stations. They are inflated and thick (*H. crassimargo* Norm.), the umbilical depressions often wide and deep; the segments of the last whorl usually 6 or 7, the sutures pretty deeply incised, and the surface smoother than in the North Atlantic form.

Pacific. 660–1879 fathoms; in company with *H. latidorsatum*.

H. globigeriniformis Park. & Jones.

Lituola nautiloidea var. *globigeriniformis* Park. & Jones, 1865, North Atl. & Arct. Oc., Philos. Transact., LV. p. 407, Pl. XV. Figs. 46–47; Pl. XVII. Fig. 96.
H. globigeriniformis Br., 1884, Chall. Rep., IX. p. 312, Pl. XXXV. Figs. 10, 11.
H. globigeriniformis Goës, 1863, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 22, Pl. V. Figs. 128–133.

It is with a certain degree of hesitation that I assign a lot of more or less developed minor specimens to the above form of Parker and Jones, as they may be considered as poorly grown samples of *H. helicoideum* with only 3 or 4 segments in the outer whorl; but in all other respects they agree with *H. globigeriniformis*.

Pacific. 772–1218 fathoms; pygmy.

Caribbean Sea. 382–966 fathoms; better developed.

H. turbinatum Brady var. helicoideum, n.

Plate III. Figs. 10-13.

This may rather be considered as a type form of Brady's *H. turbinatum* (Chall. Rep., IX. p. 312, Pl. XXXV. Fig. 9), the chief difference being the regularly

constructed $2\frac{1}{2}$–3-whorled spire, with 5–6–7 segments in the outer one. The test is sometimes rough with sand grains and of a grayish hue, but sometimes polished and of a brown or reddish color. It is more inflated and larger than *H. nanum* BR. (Chall. Rep., Pl. XXXV. Figs. 6–8), but in all other respects of the same build. The umbilicus is sometimes deep, but generally very narrow, sometimes wanting. Attains a diameter of 1.5 mm.

Fig. 10, aboral side; Fig. 11, marginal-oral side; Fig. 12, with irregular spire, approaching *H. turbinatum;* Fig. 13, umbilical side.

Pacific. 885–1879 fathoms; a few starved specimens.

Caribbean Sea. 380–1630 fathoms; scarce, but well developed specimens.

H. obsoletum, n.

Plate III. Figs. 14–16.

? *H. turbinatum* EGGER, 1893, Exp. Gazelle, Bayr. Ak. Wiss., XVIII. p. 262, Pl. V. Figs. 57–59.

This may be considered as intermediate between the preceding and *H. latidorsatum*. The sutures nearly obsolete; the segments are not inflated, but the contours thick, the rounded margin without incisions, the aperture sometimes situated above the marginal suture on the obliquely set septum; umbilicus usually obsolete. The outer whorl 6-chambered; color pale yellow; surface sometimes smooth, sometimes rough. Diameter, 1–2 mm.

Fig. 14, marginal-oral side; Fig. 15, spiral side; Fig. 16, umbilical view.

Caribbean Sea. 382–1630 fathoms; scarce.

H. fontinense (TERQ.) BRADY.

H. fontinense (TERQUEM), BR., 1884, Chall. Rep., IX. p. 305, Pl. XXXIV. Figs. 1–4.

This large and flat form has been met with at three stations only in the Pacific. Younger ones are hardly distinguishable from *H. compressum* GOËS.

Pacific. 660–995 fathoms; not plenty.

ALLIED FORM:—

H. compressum GOËS.

Lituolina irregularis var. *compressa* GOËS, 1882, Ret. Rhizop. Carib. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 141, Pl. XII. Figs. 421–423.

H. emaciatum BR., 1884, Chall. Rep., IX., p. 305, Pl. XXXIII. Figs. 26–28.

To be considered a pygmy variety of *H. fontinense* BR. Full grown specimens have also the aperture situated on the top of the septal wall; but in those which have not yet put on the Nodosaria stage it is marginisutural. It has often a brown or brick color.

Caribbean Sea. 196–463 fathoms; not common.

H. agglutinans D'ORB.

Spirolina agglutinans D'ORB., 1846, Bass. tert. Vienne, p. 137, Pl. VII. Figs. 10–12.
H. agglutinans BR., 1884, Chall. Rep., IX. p. 301, Pl. XXXII. Figs. 19–26.
H. agglutinans GOËS, 1893, Sv. Vet. Ak. Hdl., XXV. 9, p. 23, Pl. V. Figs. 140, 141.

A few but well developed samples have been met with in the Caribbean Sea, at 778 fathoms.

H. lituolinoideum, n.

Plate III. Figs. 17–20.

It would perhaps be consistent with a more philosophic view to range this form as a simplified variety of *Lituola nautiloidea* (LMCK.) D'ORB.,[1] from which it differs only in smaller size and undivided chambers. It measures only 2.5 mm. in length; although the labyrinthic construction is not at all developed, the aperture is still represented by numerous pores gathered mostly at the centre of the septum. The color is grayish with a flush in brown.

Fig. 17, lateral; Fig. 18, marginal view; Fig. 19, the top with apertural poration; Fig. 20, transverse section of a chamber.

Gulf of Mexico. 347–727 fathoms; rare.

CYCLAMMINA (BRADY) NORMAN.

C. cancellata NORMAN.

C. cancellata (BR.) NORM., 1876, Valorous Cruise, 1875, Proc. Roy. Soc., XXV. p. 214.
C. cancellata BR., 1884, Chall. Rep., IX. p. 351, Pl. XXXVII. Figs. 8–16.

Is met with in two forms, one more outspread and flat, with somewhat extenuated margin; and another with rounded margin and relatively thicker growth; the former has generally thinner walls and a lighter color.

Pacific. 660–995 fathoms; not scarce; the greater part are large and flat specimens.

Caribbean Sea. 196–1830 fathoms; not so common; smaller, browner, and more round-edged form.

ALLIED FORM:—

C. pusilla BRADY.

C pusilla BR. (1881), 1884, Chall. Rep., IX. p. 353, Pl. XXXVII. Figs. 20–23.
C. pusilla GOËS, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 32, Pl. VI. Figs. 242–244.

Cannot be considered as specifically distinct from the type.

Pacific. 772–1201 fathoms; scarce.

Caribbean Sea. 382–1920 fathoms; not common.

[1] *L. nautiloides* D'ORB., 1840, Mém. Soc. Géol. Fr. (1), IV. p. 29, Pl. II. Figs. 28–31.

TROCHAMMINA Park. & Jones.

T. ringens Brady.

T. ringens Br. (1879), 1884, Chall. Rep., IX. p. 343, Pl. XL. Figs. 17, 18.

Of this form but a small quantity of specimens have been brought home from both sides of the Isthmus.

Pacific. 1201 fathoms; very scarce.

Caribbean Sea. 347–769 fathoms; scarce.

T. pauciloculata Brady.

T. pauciloculata Br. (1879), 1884, Chall. Rep., IX. p. 344, Pl. XLI. Figs. 1, 2.

Very few samples met with.

Pacific. 1201 fathoms; rare.

T. galeata Brady.

T. galeata Br. (1881), 1884, Chall. Rep., IX. p. 344, Pl. XL. Figs. 19–23.

A single specimen only has been met with.

Caribbean Sea. 169 fathoms.

T. trullisata Brady.

T. trullisata Br. (1879), 1884, Chall. Rep., IX. p. 342, Pl. XL. Figs. 13–16 (14–16 a somewhat modified variety).

Both larger and pygmy forms have been met with, but in small number only. It is very nearly allied to *Cyclammina*, its chief difference from that genus being in its smaller number of segments (7 or 8) and its nearly simple shell wall.

Pacific. 978–1218 fathoms; rare.

Caribbean Sea. 347–1635 fathoms; scarce.

T. conglobata Brady.

T. conglobata Br., 1884, Chall. Rep., IX. p. 341, Pl. XL. Figs. 8, 9.

Is to be considered as a more mature form of the preceding.

Caribbean Sea. 399–1345 fathoms; rare.

T. proteus Karr.

T. proteus Karr., 1866, Wiener Sandstein, Wiener Ak. Sitz. Ber., LII., p. 494, Pl. I. Fig. 8.

T. proteus, lituiformis, Br. (1879), 1884, Chall. Rep., IX. pp. 341, 342, Pl. XL. Figs. 1–7.

It has a tendency to grow out in a more or less straight tube and becomes then = *T. lituiformis* Br., which cannot properly be ranked as distinct, nor under particular varietal denomination.

Caribbean Sea. 382-1630 fathoms.

AMMODISCUS Reuss.

A. incertus d'Orb.

Operculina incerta d'Orb., 1839, For. Cuba, p. 19, Pl. VI. Figs. 16, 17.
Trochammina incerta Goës, 1882, Ret. Rhizop. Carib. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. XI. Figs. 404, 405.
A. incertus, tenuis Br., 1884, Chall. Rep., IX. pp. 330, 332, Pl. XXXVIII. Figs. 1–6.
A. incertus Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 31, Pl. VI. Figs. 238–241.

In the depths of the Pacific this form attains a considerable development, and is represented in certain localities in great abundance. *A. tenuis* Br., with large initial chamber and 5–7 whorls only, is usually associated with the type, and is to be considered as a megalasphæric or more mature form of that. The color of both varies from reddish brown to straw-yellowish.

Pacific. 660–1132 fathoms; in greatest abundance at 1000 fathoms.
Caribbean Sea. 382–1830 fathoms; scarce, and not so highly developed.

HORMOSINA Brady.

H. globulifera Brady.

H. globulifera Br. (1879), 1884, Chall. Rep., IX. p. 326, Pl. XXXIX. Figs. 1–6.
H. globulifera Goës, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 29, Pl. VI. Figs. 218, 219.

Not quite typical samples have been brought home. The produced neck, that may be considered as the most prominent feature of Brady's form, is often wanting; the surface is sometimes not as smooth as in this, and multilocular samples are rare; unilocular ones much resemble smooth forms of *Saccammina*. When the shell becomes more rough, the multilocular form may be difficult to distinguish from *Reophax pilulifer* Br.

Pacific. 885–1879 fathoms; not common.
Caribbean Sea. 1035 fathoms; not common.

H. ovicula Brady var.

Plate IV. Figs. 1–3.

H. ovicula Br. (1879), 1884, Chall Rep., IX. p. 327, Pl. XXXIX. Figs. 7–9.

Very variable in size and length and narrowness of the chamber-necks. In some instances the necks are nearly wanting and substituted by deep impressions; such forms are often hardly distinguishable from the preceding. Our form has usually more globular segments than that represented by Brady. The color is usually brick-red or reddish brown.

Pacific. 789–1879 fathoms; scarce and small.
Caribbean Sea. 420–1830 fathoms; not so rare.

ALLIED FORM:—

H. Carpenteri BRADY.

H. Carpenteri BR. (1881), 1884, Chall. Rep., IX. p. 327, Pl. XXXIX. Figs. 14–18.

Cannot justly be specifically distinguished from the preceding, intermediate forms often being met with; but it is rather to be considered as a more mature form of that species.

Caribbean Sea. 420 fathoms. Rare.

WEBBINA d'ORB.

W. clavata PARK. & JONES.

Trochammina irregularis clavata, PARK. & JONES, 1860, For. Chellaston, Qu. Journ. Geol. Soc., XVI. p. 304.
W. clavata BR., 1884, Chall. Rep., IX. p. 349, Pl. XLI. Figs. 12–16.
W. clavata, GOËS, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 32, Pl. VI. Figs. 245, 246.

Seems to be somewhat more developed and stouter than the North Atlantic form. The neck is sometimes tortuous and unattached to the adherent rock or shell débris. Brown, sometimes straw-colored.

Pacific. 660–1201 fathoms; not very plenty.
Caribbean Sea. 1399-1630 fathoms; not plenty.

VALVULINA d'ORB.

V. fusca WILLIAMS.

Rotalina fusca WILL., 1858, Rec. Foramf. Great Brit., p. 55, Pl. V. Figs. 114, 115.
V. fusca BR., Chall. Rep., IX. p. 392, Pl. XLIX., Figs. 13, 14.
V. fusca GOËS, 1893, Arct. & Scand. Foramf. Sv. Vet. Ak. Hdl., XXV. 9, p. 39, Pl. XIII. Figs. 333–355.

Between this form and *Valv. austriaca* d'ORB., no other difference can be traced than in the number of segments in the outer whorl, which is about 6 in *austriaca* and 3–5 in our form; besides the *austriaca* is a pygmy.

Caribbean Sea. 169–730 fathoms. Scarce.

CLAVULINA d'ORB.

C. rudis COSTA.

Plate IV. Figs. 4–8.

Glandulina rudis COSTA, 1855, Marna terz. Messina, Mem. Napoli, II. p. 142, Pl. I. Figs. 12, 13.
C. cylindrica HANTKEN, 1875, Clav. Szab. Schichte, Jhb. ungar. geol. Anstalt., IV. p. 18, Pl. I. Fig. 8.

C. cylindrica Karrer, 1877, Hochquell. Wasserleit., Abh. geol. Reichsanst. Oesterr., IX. p. 373, Pl. XVI. Fig. 4.
Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 62, Pl. IV. Figs. 77–81.
Brady, 1884, Chall. Rep., IX. p. 396, Pl. XLVIII. Figs. 32–38.
C. rudis Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 43, Pl. VIII. Figs. 408–412.

This form together with *C. Soldanii* is a very prominent constituent of the bottoms in certain localities of the Caribbean Sea, though sparsely represented in the collections of the "Albatross."

It is very variable in size, smoothness, and shape, from slender cylindric to broad ovoid.

Caribbean Sea. 150–300 fathoms; not rare (Goës).

C. communis d'Orb.

Plate IV. Figs. 9-15.

C. communis d'Orb. (1826), 1846, Bass. tert. Vienne, p. 196, Pl. XII. Figs. 1, 2.
Text. gibbosa f. ligenerina Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 79, Pl. V. Figs. 162–164; *forma lævigata*, pygmy, smooth, with the larval stage reduced, sometimes biserial, aperture often porous.
C. communis Br., 1884, Chall. Rep., IX. p. 394, Pl. XLVIII. Figs. 1–13.
C. communis Goës, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 20, Pl. VIII. Figs. 356, 367 (*forma lævigata*).

C. communis occurs in two forms, one slender and smoother, and a stouter one. The former, Plate IV. Figs. 9–15, seems to belong only to the Caribbean Sea, the latter is common to both seas; the larval stage is in the former very reduced and short, as the whole colony is usually of smaller size, the surface white and nearly smooth, the shell agglutinated of fine calcareous matter.

Pacific. 772–1471 fathoms, large form; at 1100 fathoms plentiful.

Caribbean Sea. 25–1830 fathoms; *forma lævigata* 300 fathoms (Goës).

Allied Form:—

C. eocæna Gümbel. Plate IV. Figs. 16–25.

C. eocæna Gümbel, 1868, For. Nordalp. Eocän, K. Bayr. Ak. Wis. Abhdl., X. 2, p. 601, Pl. I. Fig. 2.
Valvulina triangularis v. *eocæna* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 88, Pl. XI. Figs. 401–403.
C. communis f. eocæna Goës, 1893, Arct. & Scand. Foramf., Sv. Vet. Akad. Hdl., XXV. 9, p. 41, Pl. VIII. Figs. 368–377.

Thicker and of coarser sand construction than the type. It has often a tendency to labyrinthic structure; the form is sometimes cylindric, but often the test widens with age, assuming a conical shape.

Caribbean Sea. 68–1830 fathoms. Not common.

C. parisiensis d'Orb.

C. parisiensis d'Orb., 1826, Tab. Méth., Ann. Sci. Nat., VII. p. 268, Mod. 66.
C. parisiensis Br., Chall. Rep., IX. p. 395, Pl. XLVIII. Figs. 14–18.
Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Akad. Hdl., XIX. 4, Plate VI. Figs. 185, 186.
C. parisiensis Goës, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 71, Pl. VIII. Figs. 378–386.

Attains in Caribbean Sea a high development, and in its construction sponge needles are often found mixed with sand and calcareous detritus.

Caribbean Sea. 45–227 fathoms.

Allied Form:—

C. textularioidea Goës. Plate IV. Figs. 26–38.

T. sagittula f. bigenerina Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 78, Pl. V. Figs. 159, 160, ?161.
C. parisiensis f. textularioidea Goës, 1892, Arct. & Scand. Rhizop., Sv. Vet. Ak. Hdl., XXV. 9, p. 42, Figs. 387–399.

Has nearly the same disposition of the segments as *Bigenerina nodosaria* d'Orb., but the larval stage is more flattened and carinate. It attains a length of 5–6 mm., and is very abundant in certain localities of the Caribbean Sea.

Caribbean Sea. 150–300 fathoms (Goës).

C. angularis d'Orb.

C. angularis d'Orb., 1826, Tab. Méth., Ann. Sci. Nat., VII. p. 268, Pl. XII. Fig. 7.
Valvul. triangularis d'Orb. *forma clavulina* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 86, Pl. XI. Figs. 387–389.
C. angularis Br., 1884, Chall. Rep., IX. n. 396, Pl. XLVIII. Figs. 22–24.

A shallow water form, but which also affects deeper water in the Caribbean Sea.

Caribbean Sea. 300 fathoms (Goës).

C. Soldanii Park. & Jones.

Plate IV. Figs. 39-46.

Lituola Soldanii P. & J., 1860, Quart. Journ. Geol. Soc., XVI. p. 307.
Valvulina triangularis var. *polyphragma* Goës, 1882, Sv. Vet. Akad. Hdl., XIX. 4, p. 87, Pl. XI. Figs. 390–400.
Haplostiche Soldanii Br., 1884, Chall. Rep., XIX. 318, Pl. XXXII. Figs. 12–18.
C. Soldanii Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 42, Pl. VIII. Figs. 400–407 (pygmy forms).

This conspicuous form reaches a high development in the Caribbean Sea, particularly in depths of 200–300 fathoms. It assumes many forms from slender Clavulinæ to egg-shaped ones. Generally the larval stage is nearly obsolete,

tri-quadriserial, but the slender forms, which are very seldom met with, display very plainly the valvuline arrangement of the segments in that stage. The scarcity of such starved forms may be the reason why *C. Soldanii* has by most authors been referred to Lituolinæ, and it may reasonably be suggested that the genus Haplostiche of Reuss may be ranked in the family of Clavulinæ.

Whether this form may be identified with *Nodosaria dubia* D'ORB., 1826, as some authors have suggested, is doubtful. It was first figured in Carpenter's Introduction, 1862, but not in a quite satisfactory way.

Van den Broeck gave in 1876 the first true representation of it under the name of *Lituola Soldanii* var. *intermedia*, Foramf. Barbade, Ann. Soc. Belg. Microsc., II. p. 74, Pl. II. Figs. 1, 3, 4, 6.

VERNEUILINA D'ORB.

V. triquetra MÜNSTER.

Textularia triquetra MÜNSTER, 1838, Roemer, Norddeutsch. tert. Meeressand, Leonh. & Bronns., Jhb. 1838, p. 384, Pl. III. Fig. 19.
V. triquetra BR., 1884, Chall. Rep., IX. p. 383, Pl. XLVII. Figs. 18–20.

Well developed samples of this conspicuous form have been met with in the Caribbean Sea only. It attains a length of 3 mm. and shows sometimes a propensity to become *bigenerine* with an aperture on the summit of the last segment (*Tritaxia*, REUSS).

Caribbean Sea. 196–210 fathoms; not very scarce.

V. propinqua BRADY.

V. propinqua BR., 1884, Chall. Rep., IX., p. 387, Pl. XLVII. Figs. 13, 14.
Forma inflata BR., Ibid., Fig. 8–11.
Forma inflata GOËS, 1891, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 33, Pl. VII. Figs. 264–266.

The two forms of this species depicted by Brady have been met with in the "Albatross" collections. The more slender and elongate, brown-rusty colored form is often affixed, and has a more rough surface than the inflated one, and shows sometimes a tendency to become textularioid, the two last chambers occupying the whole apertural face. The inflated form is usually smoother.

Pacific. 772–995 fathoms; not scarce; affixed to Rhabdammina.

Caribbean Sea. 196–1181 fathoms; scarcer. *Forma inflata*, 1345 fathoms; scarce.

V. cretacea KARRER.

KARRER, 1870, Kreidef. Leitzerdorf, Jhb. K. K. Geol. Reichsanst., XX. p. 164, Pl. X. Fig. 1.

Distinguished by its short growth, trigonal outlines, and the surface scattered over with small tubercles. It has not been met with by the "Albatross," but it

occurs sparingly in the Caribbean Sea, and is represented in my own collections by a few well developed samples.

Caribbean Sea. 300 fathoms; rare (Goës).

V. pusilla, n.

Plate V, Figs. 6–8.

Short, often nearly cylindrical, with very little inflated segments, or sometimes ovoid with inflated segments; aperture a sutural slit or an obliquely set comma-formed fissure. Pale yellow or whitish.

It differs from *V. pygmæa* (EGGER) BRADY, only in being in many instances more cylindric in its outlines and in the aperture not being suprasutural and limbate as in that; length 0.50–0.66 mm. It may be considered as an immature form of *Gaudryina scabra* BRADY.

Pacific. 995 fathoms; scarce.

TRITAXIA REUSS.

T. tricarinata REUSS.

Text. tricarinata REUSS, 1845, Böhm. Kreidef., I. p. 39, Pl. VIII. Fig. 60.
Trit. tricarinata REUSS, 1859, Westphal. Kreide, Wien. Ak. Sitz. Ber., XL. p. 228, Pl. XII. Figs. 1, 2.
Trit. tricarinata BR., 1884, Chall. Rep., IX. p. 389, Pl. XLIX. Figs. 8, 9.

Is sparingly met with on both sides of the Isthmus.

Pacific. 900 fathoms; rare.

Caribbean Sea. 300 fathoms (Goës).

GAUDRYINA D'ORB.

G. rugosa D'ORB.

The representation of this form, given by d'Orbigny in his paper on the White Chalk of Paris, Mém. Soc. Géol. France, IV. Plate IV. Figs. 20, 21, does not well exhibit its most prominent feature, which is the pyramidal shape of its immature or larval stage. Reuss, in his Foramf. d. Tertiäre Schichten nördl. und mittl. Deutschl., Wien. Ak. Sitz. Ber., XVIII. p. 244, Pl. VI. Fig. 61, has furnished a more satisfactory design, though even this in the same respect is not quite satisfactory.

Brady, 1884, in Chall. Rep., IX. Pl. XLVI. Figs. 14–16, has better succeeded in giving a more exact representation of this form. It has often a tendency to become *bigenerina*-formed, with a roundish small aperture on the summit or on the side of the last segment (*Plectina*, Marson).

In the great depths on both sides of the Isthmus it attains a great development, individuals of 4 mm. length not being rare.

Pacific. 770–1132 fathoms.

Caribbean Sea. 382–1345 fathoms; very scarce.

It may be questioned if a lot of other described "species" should not be assigned to this form ; such as *Gaudr. solita* SCHWAGER, *G. Reussi, obliqua, megastoma, nova-zelandica, capitata,* and *insecta* STACHE.

A more pointed, slender, emaciated form (Pl. V. Figs. 9–10) is often met with in the Caribbean Sea. Such a form is described by Goës, Ret. Rhizop. Caribb. Sea, Sv. Vet. Akad. Hdl., XIX. 4, p. 83, Pl. VI. Figs. 181, 182, under the name of *Text. pupoides* var. *conica.*

G. pupoides D'ORB.

G. pupoides D'ORB., 1840, For. Craie blanc Paris, Mém. Soc. Géol. France, IV. p. 44, Pl. IV. Figs. 22–24.

? *G. pupoides* D'ORB., 1846, Bass. tert. Vienne, p. 197, Pl. XXI. Figs. 34–36.

To this species I assign a somewhat compressed form that has been met with in the Pacific, in my own collections also represented from the Caribbean Sea. In all points it agrees with d'Orbigny's form from the white chalk of Paris. The length varies from 0.50–1 mm.

Pacific. 1132–1201 fathoms ; not very scarce.

Caribbean Sea. 200–300 fathoms ; scarce.

ALLIED FORMS : —

1. **G. subrotundata** BRADY.

BRADY, Chall. Rep., IX. p. 380, Pl. XLVI. Fig. 13.

Text. pupoides GOËS, 1884, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., p. 81, Pl. VI. Figs. 173–178.

Gaudr. pupoides GOËS, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, Pl. VII. Figs. 267–277.

Not much or not at all compressed, larger than the type.

Caribbean Sea. 200–300 fathoms.

2. **G. prælonga** KARRER.

KARRER, 1877, Hochquell. Wasserleit. Abh. geol. Reichs. Anstalt. Oesterreichs, IX. p. 374, Pl. XVI. Fig. 6.

? *Gaudr. subrotundata* SCHWAG., 1866, For. Kar Nikob., Novara Exped., Geol., Theil II. p. 198, Pl. 4, Fig. 9.

Extenuated and produced in length.

Caribbean Sea. 382 fathoms ; scarce.

G. scabra BRADY.

G. scabra BR., 1887, Chall. Rep., IX. p. 381, Pl. XLVI. Fig. 7.

This distinguished form is well represented in the "Albatross" collections from both sides of the Isthmus. The test is nearly smooth, of brownish yellow color.

Pacific. 660–995 fathoms.
Caribbean Sea. 347–420 fathoms; not scarce.

G. chilostoma Reuss.

Textul. chilostoma v. Reuss, 1852, Septar. Thon Stettin, Ztsch. deut. geol. Gesellsch., IV. p. 18.
G. chilostoma Reuss, 1865, For. deutsch. Septar. Thon, Wien. Ak. Dkschr., XXV. p. 120, Pl. I. Figs. 5–7.
G. pupoides, G. pupoides var. *chilostoma* Br., 1884, Chall. Rep., IX. p. 378, Pl. XLVI. Figs. 1–6.
G. chilostoma Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 34, Pl. VII. Figs. 278–280.

In his well known memoir, For. Challenger Rep., IX., Brady has without sufficient reasons assigned this form to d'Orbigny's *G. pupoides*, while it would have been more suitable and in more accordance to d'Orbigny's delineation of his *pupoides* to ascribe Brady's *G. subrotundata* (Schwager) to this form.

Our form has a very narrow and reduced larval stage. Height 2.5 mm.

Pacific. 885 fathoms. Very scarce.

TEXTULARIA Defr.

T. agglutinans d'Orb.

T. agglutinans d'Orb., 1839, For. Cuba, p. 144, Pl. I. Figs. 17, 18.
T. sagittula var. *agglutinans* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. V. Figs. 140–143.
T. agglutinans Br., 1884, Chall. Rep., IX. p. 363, Pl. XLIII. Figs. 1–4.

The form represented by d'Orbigny seems not to be carinated at the younger stage, as is not unfrequently the case. Young samples present also a more elliptical oval end than the mature ones, which have it nearly round. The former are therefore not easily distinguished from *T. sagittula* forma *recens*. In the tropical seas this form is seldom, if ever, agglutinated of siliceous sand, but of calcareous débris and detritus. It is often smoother than the Northern form.

Caribbean Sea. 169 fathoms; not plenty.

T. sagittula var. cuneiformis d'Orb.

T. cuneiformis d'Orb., 1839, For. Cuba, p. 147, Pl. I. Figs. 37–39.
T. sagittula Br., 1884, Chall. Rep., IX. p. 361, Pl. XLII. Figs. 17, 18.
T. sagittula var. *cuneiformis* Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 36, Pl. VII. Figs. 288–290.

A shallow-water form, that often occurs in the Caribbean Sea. It is not very distinct from its type that has its flourishing state in the later tertiarian strata.

Its variety with dentate margin, = *T. pectinata* Reuss, affects deeper water in the Caribbean Sea.

Caribbean Sea. 50–300 fathoms.

T. luculenta Brady.

T. luculenta Br., 1884, Chall. Rep., IX, p. 364, Pl. XLIII. Figs. 5–8.

Flat and compressed, lanceolate, its prominent feature being the extra sutural position of the aperture; sometimes it has its place on the summit of the last segment. *T. Sauleyana* d'Orb., For. Cuba, p. 146, Pl. I. Figs. 21, 22, seems to be a pygmy form of this; in which case Brady's denomination should not take the preference.

Caribbean Sea. 382 fathoms; very scarce.

T. concava Karrer.

Plecanium concavum Karrer, 1868, Miocän Kostej., Wien. Ak. Sitz. Ber., LVIII. p. 129, Pl. I. Fig. 3.

T. concava Br., 1884, Chall. Rep., IX. p. 360, Pl. XLII. Figs. 13, 14, Pl. XLIII. Fig. 11.

This form seems to be an abbreviated variety of *T. luculenta*.

Caribbean Sea. 382 fathoms, together with *T. luculenta*. Very rare.

T. lævigata d'Orb.

T. lævigata d'Orb., 1846, For. Bass. tert. Vienne, p. 243, Pl. XIV. Figs. 14–16.

In tropical seas we often meet with small Textularia not much agglutinating with more or less tapering and pointed juvenile stage, rounded edges, and oval or nearly circular apertural face. There is no form on record but *T. lævigata* d'Orb. that can be identified with such a form, although it seems that d'Orbigny's form grows twice as large as ours. *T. pygmæa* or *aciculata* d'Orb. is generally much compressed, and may not perhaps properly be identified with our form.

T. Caribæa d'Orb. seems to belong to this set of smaller Textulariæ, but it may be suggested that d'Orbigny's figure rather represents a *Bolivina* than a *Textularia*.

Caribbean Sea. 196 fathoms. Very scarce.

T. solita Schwag. var. inflata, n.

Plate V. Figs. 1-3.

Our form is scarcely agglutinant, and differs from the type in having the last segments much inflated, the apertural face being consequently broad oval; the aperture is somewhat suprasutural and represented by a long often slight limbated slit, sometimes interrupted in the middle.

Pacific. 1201 fathoms; very scarce.

T. rugosa REUSS, var.

Plate V. Figs. 4, 5.

Plecanium rugosum REUSS, 1869, Oligocän v. Gaas, Wien. Ak. Sitz. Ber., LIX. p. 453, Pl. I. Fig. 3.
T. rugosa BR., 1884, Chall. Rep., IX. p. 363, Pl. XLII. Figs. 23, 24.
? *T. flabelliformis* GÜMB., 1868, Nordalp. Eocän, K. Bay. W. Ak., Abh. X. p. 649, Pl. II. Fig. 83.
? *T. Jonesi* BR., 1876, Carb. & Perm. For., Pal. Soc., XXX. p. 133, Pl. X. Figs. 20–22.
? *T. cuneiformis* JONES, 1850, King's Monogr. Perm. Foss., p. 18, Pl. VI. Fig. 6.

Our form does not quite agree with the representations given by Reuss and Brady, for in their figures the prominent rib in the middle of the test is wanting, making our form in this respect approach *T. carinata* D'ORB.

It has a gray clay color. The contours are like those of *T. folium* PARK. & JONES.

Caribbean Sea. 196–210 fathoms; scarce.

T. conica D'ORB.

T. conica D'ORB., 1839, For. Cuba, p. 143, Pl. I. Figs. 19, 20. (Much compressed.)
T. cuneiformis var. *conica* WILLIAMS., Rec. For. Gr. Brit., p. 75, Pl. VI. Figs. 160, 161.
T. sagittula var. GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. V. Figs. 150–158.
T. trochus VAN DEN BROECK, 1876, For. Barbade, An. Soc. Belg. Micr., II. p. 132, Pl. III. Figs. 11, 12.
T. conica, trochus (partly) BR., 1884, Chall. Rep., IX. p. 365, Plate XLIII. Figs. 13–19, Pl. CXIII. Fig. 1.

Sometimes more or less compressed, sometimes circular in transverse section; the sutures often with a tendency to become limbate or "jugate." Some more compressed forms are often difficult to distinguish from thicker forms of *sagittula* DEFR. Large samples of the circular form have their segments sometimes scantily subdivided with a few secondary walls.

Caribbean Sea. 300 fathoms (Goës).

T. trochus D'ORB.

T. trochus D'ORB., 1840, For. Craie bl. Paris, Mém. Soc. Géol. Fr., IV. p. 45, Pl. IV. Figs. 25, 26.
T. trochus GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 80, Pl. V. Figs. 167–170; Pl. VI. Figs. 171, 172.
T. trochus (partly) BR., 1884, Chall. Rep., IX. p. 366, Pl. XLIV. Figs. 1–3.

It may be with some degree of hesitation that our prominent Caribbean form with its labyrinthic segments is identified with d'Orbigny's form, the inner structure of which is uncertain. In the younger and half-grown stages the

circumference is circular, while the mature stage is more or less flattened. The figure of d'Orbigny exhibits a young stage or pygmy form with circular basis, and resembles in all respects our form in its young state.

Brady in Chall. Rep. has apparently confounded two different forms under *T. trochus* of d'Orb. In Plate XLIII., Figures 15–19 should be assigned to *T. conica* d'Orb.; and in Plate XLIV., Figures 1–3 to *T. trochus* d'Orb., to which *T. Baretti*, Figures 6–8, also belongs.

T. trochus attains in the Caribbean Sea stout dimensions.

Caribbean Sea. 262–400 fathoms; not scarce.

BIGENERINA d'Orb.

B. capreolus d'Orb.

Vulvulina capreolus d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p 264, Pl. XI. Figs. 5–8, Mod. 59.
B. capreolus Br., 1884, Chall. Rep., IX. p. 372, Pl. XLV. Figs. 1–4.

Caribbean Sea. 399 fathoms; very rare.

Allied Form:—

B. pennatula Batsch.

Nautilus pennatula Batsch, 1791, Conchyl. Seesands, Pl. IV. Fig. 13.
Vulvul. elegans d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 264.
B. pennatula Br., 1884, Chall. Rep., IX. p. 373, Pl. XLV. Figs. 5–8.

Is to be considered as a more advanced stage of the preceding.
Caribbean Sea. 399 fathoms; scarce.

B. nodosaria d'Orb.

B. nodosaria d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 261, Pl. XI. Figs. 9–11, Mod. 57.
B. agglutinans d'Orb., 1846, Bass. tert. Vienne, p. 238, Pl. XIV. Figs. 8–10.
Text. sagittula var. Goës, 1882, Ret. Rhiz. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. V. Figs. 133–139.
B. nodosaria Br., 1884, Chall. Rep., IX. p. 369, Pl. XLIV. Figs. 14–18.
B. nodosaria Goës, 1874, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 37, Pl. VII. Figs. 313–323.

Is not met with in the "Albatross" dredgings, but attains in the Caribbean Sea a high development, although it is of rare occurrence.

Caribbean Sea. 300 fathoms (Goës).

BULIMINA D'ORB.

B. pyrula D'ORB.

B. pyrula D'ORB., 1846, Bass. tert. Vienne, p. 184, Pl. XI. Figs. 9, 10.
B. pyrula BR., 1884, Chall. Rep., IX. p. 399, Pl. L. Figs. 7–12.

This species attains great development in the seas on both sides of the Isthmus, individuals of 1.75 to 2 mm., and much inflated, not being scarce. It is often provided with spines on the earlier segments (var. *spinescens* BR., Figs. 11, 12).

Pacific. 772 fathoms; not scarce.

Caribbean Sea. 463 fathoms; not scarce.

ALLIED FORM:—

B. ellipsoides COSTA.

B. ellipsoides COSTA, 1854, Pal. Napol., II. p. 265, Pl. XV. Fig. 9.
B. ovata BR., 1884, Chall. Rep., IX. p. 400, Pl. L. Fig. 13.
B. ellipsoides GOËS, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9 p. 45, Pl. VIII. Figs. 431–436.

In the Challenger Report, IX., Brady has designed our form under d'Orbigny's denomination of *B. ovata*. But that form is more slender, and provided with more numerous visible segments.

The two forms are however too much allied to be specifically distinguishable. Our form varies much in shape from cylindric to ovoid and fusiform, the latter being nearly identical with *B. affinis*.

Pacific. 695–1832 fathoms; not scarce.

Gulf of Mexico. 210–978; not scarce.

B. aculeata D'ORB.

B. aculeata D'ORB., 1826, Tab. Méth., Ann. Sc. Nat., VII. p. 269.
B. aculeata GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. IV. Figs. 82, 83 (young).
B. aculeata BR., 1884, Chall. Rep., IX. p. 406, Pl. LI. Figs. 7–9.

It is not without some hesitation that our form may be identified with *B. aculeata* of d'Orbigny, since Soldani's figure cited does not afford sufficient accuracy for an exact comparison. Our form agrees best with Williamson's *B. pupoides* var. *spinulosa* (Rec. For. Gr. Brit., p. 62, Pl. V. Fig. 128), and also with Brady's Fig. 8, Pl. LI. in Chall. Rep.

Caribbean Sea. 500–724 fathoms; scarce.

B. inflata Seguenza.

B. inflata Seg., 1862, Rhizop. Catania, Atti Accad. Giocnia (2.), XVIII. p. 19, Pl. I. Fig. 10.
B. inflata Br., 1884, Chall. Rep., IX. p. 406, Pl. LI. Figs. 10–13.

This singular form has not been met with in any abundance, but the specimens have a pretty high development. It cannot be specifically distinguished from d'Orbigny's *B. Buchiana*, the main difference being the spinous lower margins of the segments in d'Orbigny's form ; although among the figures of d'Orbigny in Bass. tert. Vienne one is depicted with the corresponding margins crenulated.

Pacific. 695–995 fathoms ; scarce.
Caribbean Sea. 724 fathoms. (1 sample only.)

B. elegantissima d'Orb.

B. elegantissima d'Orb., 1839, Voy. Amér. Mér., V. p. 51, Pl. VII. Figs. 13, 14.
B. elegantissima Goës, 1882, Ret. Rhiz. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 66, Pl. IV. Fig. 88, var.; Figs. 95–98.
B. elegantissima Br., 1884, Chall. Rep., IX. p. 402, Pl. L. Figs. 20–22.

Is scantily met with in the Caribbean Sea and always of pygmy size; often it verges into *B. subteres* Brady.

Caribbean Sea. 300 fathoms ; scarce (Goës).

VIRGULINA d'Orb.

V. squamosa d'Orb.

V. squamosa d'Orb., 1826, Tab. Méthod., An. Sc. Nat., VII. p. 267, Mod. No. 64.
V. punctata d'Orb., 1839, For. Cuba, p. 139, Pl. I. Figs. 35, 36.
V. squamosa Goës, 1882, Ret. Rhizop. Carib. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 67, Pl. IV. Figs. 99, 100, 106, 107.
V. squamosa Br., 1884, Chall. Rep., IX. p. 415, Pl. LII. Fig. 9 (turning in *subsquamosa* Egger).
V. squamosa Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 47, Pl. IX. Figs. 454–456, 460.

A few samples, sometimes turning in the variety *V. Schreibersiana* Czjz., have been met with.

Pacific. 978–1218 fathoms; scarce.
Caribbean Sea. 250–300 fathoms (Goës).

Allied Form:—

V. subsquamosa Egger.

V. subsquamosa Egger, 1857, Mioc. Ortenburg, Leonh. & Bronns Jhb. 1857, p. 295, Pl. XII. Figs. 19–21.

V. subsquamosa Br., 1884, Chall. Rep., IX. p. 415, Pl. LII. Figs. 7, 8, 11.
V. subsquamosa Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 49, Pl. IX. Figs. 473, 474.

An abbreviated, thick, and somewhat curvated form of the type.
Pacific. 1132 fathoms

V. subdepressa Brady.

V. subdepressa Br., 1884, Chall. Rep., IX. p. 416, Pl. LII. Figs. 14–17.

This form can scarcely be distinguished from *Boliv. porrecta* Brady. It has scantily been met with in the Pacific.
Pacific. 730–1201 fathoms ; rare.

BOLIVINA d'Orb.

B. punctata d'Orb.

B. punctata d'Orb., 1839, Voy. Amér. Mérid., V. p. 63, Pl. VIII. Figs. 10–12.
B. punctata Br., 1884, Chall. Rep., IX. p. 417, Pl. LII. Figs. 18, 19 (slender form).
B. punctata Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 49, Pl. IX. Figs. 475–480.

This form reaches a high development in the tropical seas, particularly in the Pacific (0.85 mm. in length).
Pacific. 695–1882 fathoms.
Caribbean Sea. 300 fathoms (Goës).

Allied Form: —

B. dilatata Reuss.

Boliv. dilatata Reuss, 1849, Neue For. Oesterreichs, Wien. Akad. Dkschr., I. p. 381, Pl. XLVIII. Fig. 15.
Bulim. punctata var. Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. IV. Figs. 124–126 (young).
Boliv. dilatata Br., 1884, Chall. Rep., IX. p. 418, Pl. LII. Figs. 20, 21.

The very broad form of *B. dilatata* is easily distinguished from *B. punctata*, but sometimes intermediate forms are met with having narrower contour and less sharp edge, which may questionably be ascribed to the form on record.
Pacific. 695–1832 fathoms ; together with the type.
Caribbean Sea. 300 fathoms ; not rare.

B. Beyrichi Reuss.

Boliv. Beyrichi Reuss, 1851, Septar. Thon. Berl., Zeitschr. deut. geol. Gesellsch., III. p. 83, Pl. VI. Fig. 51.
Bulim. punctata var. *decurrens* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. p. 71, Pl. IV. Fig. 127.
Boliv. Beyrichi Br., 1884, Chall. Rep., IX. p. 422, Pl. LIII. Figs. 1–4.

Usually stouter than *punctata*, and distinguished by the lower angle of the segment being produced in a nearly vertical spine.

Caribbean Sea. 300 fathoms; not scarce (Goës).

B. plicata d'Orb.

B. plicata d'Orb., 1839, Voy. Amér. Mérid., V. 62, Pl. VIII. Figs. 4–7.
B. plicata Br., 1870, For. Tidal Riv., An. Mag. Nat. Hist. (4.), VI. p. 302, Pl. XII. Fig. 7.
B. plicata Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 51, Pl. IX. Figs. 487, 488.

This should more properly be arranged as an allied form of *B. punctata*, for when the folds or grooves of the sutures are reduced to some extent, there will be scarcely any characteristic left for distinguishing the two forms. Our specimens are not so pointed, but more rounded at the apex of the young stage, but that feature may perhaps belong to a more developed or mature stage of the initial or larval one. It is generally more broad than *B. punctata*, but specimens with the two margins nearly parallel are also met with.

Pacific. 730 fathoms. Scarce.

B. costata d'Orb.

B. costata d'Orb., 1839, Voy. Amér. Mérid., V. p. 62, Pl. VIII. Figs. 8, 9.
B. costata Br., 1884, Chall. Rep., IX. p. 426, Pl. LIII. Figs. 26, 27.

Being a shallow-water form, but a single specimen has been met with. It has a somewhat narrower contour than the form designed in Chall. Rep. *B. costata* d'Orb., 1846, For. Bass. tert. Vienne, p. 239, Plate XXI. Figs. 44, 45, seems to deviate somewhat from the type.

Pacific. 730 fathoms.

B. caribæa Goës.

B. costata Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 71, Pl. IV. Figs. 129–132.

This species has been recorded under the head of *B. costata* d'Orb., from which it differs through its more compressed outlines, stronger and more regularly disposed ribs, which have a tendency to be produced to spines at the lower margin and particularly at the outer lower angle of the segments. The pores are often large and scattered. Often the contour of the test is much like the representation of *Sagrina pulchella* given by d'Orbigny in his For. Cuba. It is always of a pygmy size, from 0.30 to 0.50 mm. in height.

Caribbean Sea. 300 fathoms; not rare (Goës).

CASSIDULINA d'Orb.

C. subglobosa Brady.

C. subglobosa Br. (1881), 1884, Chall. Rep , IX. p. 430, Pl. LIV. Fig. 17.

This comparatively stout form is not unfrequent in moderate and even greater depths on both sides of the Isthmus. It is nearly always associated with pelagic Foraminifera.

Pacific. 770–1201 fathoms; not rare.

Caribbean Sea. 382–1181 fathoms; not rare.

C. Bradyi Norman.

C. Bradyi (Norman) Br., 1884, Chall. Rep., IX. p. 431, Pl. LIV. Figs. 6–10.

Bulimina squamosa var. *subsquamosa* (partim) Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 69, Pl. IV. Figs. 111–113.

C. Bradyi Goës, 1874, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 44, Pl. VIII. Figs. 423–426.

This pygmy form occurs not very scantily in Globigerina ooze of the Caribbean Sea; it seldom attains more than a length of 0.30 mm.

Caribbean Sea. 300 fathoms; not common (Goës).

EHRENBERGINA Reuss.

E. serrata Reuss var. trigona.

Flat Form.

E. serrata Reuss, 1849, Neue For. Oesterr., Wien. Akad. Dkschr., I. p. 377, Pl. XLVIII. Fig. 7.

E. serrata Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 44, Pl. VIII. Figs. 428–430.

Trigonal Form.

E. serrata Br., 1884, Chall. Rep., IX. p. 434, Pl. LV. Figs. 2–7.

Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XXV. 9, Pl. VI. Figs. 183, 184.

The stout trigonal form designated by Brady is the variety that usually occurs in tropic seas. Von Reuss's form is more flat, and is not provided with middle crest on the spiral or ventral side.

Pacific. 1201–1322 fathoms; scarce.

Caribbean Sea. 300 fathoms; scarce (Goës).

CHILOSTOMELLA Reuss.

C. ovoidea Reuss.

C. ovoidea Reuss, 1849, Neue For. Oesterreichs, Wien. Ak. Dkschr., I. p. 880, Pl. XLVIII. Fig. 12.

C. ovoidea Br. (1879), 1884, Chall. Rep., IX. p. 436, Pl. LV. Figs. 12–23.
C. ovoidea Goës, 1891, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 53, Pl. IX. Figs. 512–516.

In the tropical seas two forms of this species are often met with. One has a slender and nearly cylindrical shape (*C. cylindroides* Reuss); the other is inflated and usually stouter, sometimes reaching a length of 1.75 mm.

Pacific. 695–1832 fathoms; not scarce.
Caribbean Sea. 1830 fathoms; rare.

UVIGERINA d'Orb.

U. pygmæa d'Orb.

U. pygmæa d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 269, Pl. XII. Figs. 8, 9, Mod. 67.
U. pygmæa Br., 1884, Chall. Rep., IX. p. 575, Pl. LXXIV. Figs. 11–14.

Shows often a tendency to become prickly, and the type form is scantily met with in the tropics. The costation is often very coarse and deep, particularly in specimens from the Pacific.

Pacific. 995 fathoms; not scarce.
Caribbean Sea. 278 fathoms.

Allied Form:—

U. aculeata d'Orb.

U. aculeata d'Orb., 1846, Bass. tert. Vienne, p. 191, Pl. XI. Figs. 27, 28.
U. aculeata Br., 1884, Chall. Rep., IX. p. 578, Pl. LXXV. Figs. 1, 2.
? *U. gracilis* Reuss, 1851, Septar. Thon. Berlin, Zeitschr. deut. geol. Gesellsch., III. p. 77, Pl. V. Fig. 39.

Often our form is more costate than aculeate, the spines usually being confined to the 2–4 last segments. D'Orbigny's figure exhibits a form with the young stage only ribbed, all other segments being spinous. It cannot reasonably be differentiated from *U. asperula* Czjz. & Reuss; and *U. Orbignyana* Czjz., 1847, For. Foss. Wien, Haid. Nat. Wiss., Abh. II. pp. 146, 147, Pl. XIII. Figs. 14–17, being intermediate forms between this variety and *pygmæa*.

Pacific. 759–1218 fathoms; not scarce.

U. Auberiana d'Orb.

U. Auberiana d'Orb., 1839, For. Cuba, p. 106, Pl. II. Figs. 23, 24.
U. asperula var. *Auberiana* Br., 1884, Chall. Rep., IX. p. 579, Pl. LXXV. Fig. 9.
U. Auberiana Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 52, Pl. IX. Figs. 494, 495.

Our form differs somewhat from d'Orbigny's type, being more cylindric and slender.

Pacific. 695–1218 fathoms.

Forma lævis Goës.

U. Auberiana Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 60, Pl. IV. Figs. 71–74 (pygmy).

Our form comes very near to *U. farinosa* Hantken (For. Clavul. Szábói Sch. 1875, Separ., Pl. VII. Fig. 6), and is in all respects but for its smooth surface of similar build as the type, the strong relationship of which it shows even by its earliest segments being provided with a few short spines or warts. Length about 0.50–1 mm.

Pacific. 600–1201 fathoms.

Caribbean Sea. 300 fathoms.

SAGRINA d'Orb.

S. pygmæa Goës.

Textul. Pennatula var. *aculeata* forma *Bigenerina* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 79, Pl. V. Figs. 165, 166.

It is with some hesitation I refer this form to a new species, for its immature stage is very much like *Loxostomum aculeatum* of Ehrenberg, the chief difference being that in his form the segments are provided with a conspicuous neck, that is wanting in our form. The nodosaria stage reaches great development in comparison with the larval stage; it is, like the latter, much compressed, and sometimes provided with a couple of longitudinal folds on each segment. It reaches seldom over 0.40 mm. in length.

Caribbean Sea. 300 fathoms; not common (Goës).

LAGENA Walk. & Boys.

L. lævis Walk. & Boys.

Serpula lævis Walk. & Boys, 1784, Test. Min., p. 3, Pl. I. Fig. 9.
Vermiculum læve Montagu, 1803, Test. Brit., p. 524.
L. lævis Br., 1884, Chall. Rep., IX. p. 455, Pl. LVI. Figs. 7–14, 30.
L. lævis Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 74, Pl. XIII. Fig. 719–722.

This has been met with, but is very scarce.

Pacific. 1132 fathoms; rare.

Allied Form:—

L. tuberculata Karrer.

L. tuberculata Karr., 1870, Kreidef. Leitzerdorf, Jhb. K. K. geol. Reichsanstalt Oesterr., XX. p. 168, Pl. I. Fig. 6.
L. tuberculata Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 75, Pl. XIII. Fig. 724.
L. aspera Br., 1884, Chall. Rep., IX. p. 457, Pl. LVII. Figs. 7–12.

An ectosolenian form, that Brady has referred to the entosolenian *L. aspera* of Reuss. It is seldom met with in the tropics.

Pacific. 1201 fathoms; rare.

L. gracillima Seguenza.

L. gracillima Seg., 1862, For. miocän. monotal. Messina, p. 51, Pl. 1, Fig. 37.
L. gracillima Br., 1884, Chall. Rep., IX. p. 456, Pl. LVI. Figs. 19–28.
L. gracillima Goës, 1891, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 75, Pl. XIII. Figs. 728–730.

This form is not seldom met with even in tropical seas, usually associated with its striated allied form, *L. distoma* Park. & Jones.

Pacific. 782–1132 fathoms; not scarce.

Caribbean Sea. 420 fathoms; rare.

L. striata d'Orb., forma perlucida Montag.

Vermiculum perlucidum Montagu, 1803, Test. Brit., p. 525, Pl. XIV. Fig. 3.
L. sulcata Br., 1884 (partly), Chall. Rep., IX. p. 462, Pl. LVII. Figs. 23, 26.
L. striata f. *costata* Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 76, Pl. XIII. Fig. 736.

This ectosolenian form has often been assigned to *L. sulcata* Walk. & Jac. but that species should be ranked in the *entosolenian* group. It is not commonly met with in the seas of the tropics.

Pacific. 1132 fathoms; rare.

L. marginata Walk. & Boys.

Serpula marginata Walk. & Boys., 1784, Test. Min., p. 2, Pl. I. Fig. 7.
L. marginata Br., 1884, Chall. Rep., IX. p. 476, Pl. LIX. Figs. 21–23.
L. marginata Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 81, Pl. XVIII. Figs. 748–751.

L. marginata assumes in tropical seas relatively immense proportions in growth, while it is often associated with pygmy forms. The margin is sometimes carinate or winged. Brady has presented good figures of such stout forms upon which many rhizopodologists should perhaps be prone to confer a special denomination. A variety with a few spines on the bottom margin is sometimes met with. It has received a special name by Schwager (*Fissurina staphyllearia*, 1866, For. Kar Nikob., Novara Reise, II. Pl. V. Fig. 24).

Pacific. 695–1201 fathoms; not rare.

Caribbean Sea. 382–1920 fathoms; not rare.

L. Orbignyana Seg. var. elongata.

This form deviates from that of Seguenza in being flask-shaped instead of having a circular contour. Brady has designed such a form between the circular ones in the Challeng. Rep., IX. Pl. LIX. Fig. 26.

Pacific. 1132–1201 fathoms; not common.

L. danica Madsen.

L. danica Madsen, 1895, Med. Dansk. geol. Foren., 1895, II. p. 196, Pl. I. Fig. 4.

Plate V. Figs. 11, 12.

Short flask-formed or nearly trigonal in its marginal somewhat bended outlines. Not much compressed, the blunt or rounded margin provided with two narrow limbs or keels commencing somewhat above the middle of the margin and widely diverging to the bottom of the test; the bottom viewed from the margin is nearly flat; it resembles somewhat *L. fimbriata* Brady, cnfr. Balkwill & Millett, For. Galway, Journ. Micr. and Nat. Sc., III., 1884, Pl. II. Fig. 5.

Pacific. 1132–1201 fathoms, associated with the preceding, with which it may be nearly allied.

L. seminiformis Schwag.

L. seminiformis Schwag., 1866, For. Kar Nikobar, Novara Reise, Geol., Theil II. p. 208, Pl. IV. Fig. 21.

L. seminiformis Br., 1884, Chall. Rep., IX. p. 478, Pl. LIX. Figs. 28–30

A single starved specimen of this form has been met with in the bottoms from "Albatross" dredgings. Its marginal wing is narrower than that of the type.

Pacific. 885 fathoms; scarce.

L. formosa Schwag.

L. formosa Schwag., 1866, For. Kar Nikobar, Novara Reise, Geol., Theil II. p. 206, Pl. IV. Fig. 19.

L. formosa Br., 1884, Chall. Rep., IX., p. 480, Pl. LX. Figs. 10, 18–20.

Has been of rare occurrence on both sides of the Isthmus. Brady's figures in Chall. Rep. representing *L. lagenoides* Will. may be reasonably referred to this form.

Pacific. 1740 fathoms.

Caribbean Sea. 724 fathoms.

L. distoma Park. & Jones.

L. distoma (Park. & Jones) Brady, 1864, Rhizop. Shetland, Transact. Lin. Soc., XXIV. p. 467, Pl. XLVIII. Fig. 6.

L. distoma Br., Chall. Rep., IX. p. 461, Pl. LVIII. Figs. 11–15.

L. distoma Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 77, Pl. XIII. Figs. 739, 740.

Sometimes this form is very faintly striated, and is then not distinguishable from *L. gracillima* Seg.

Pacific. 782–1132 fathoms.

POLYMORPHINA d'Orb.

P. ovata d'Orb.

P. ovata d'Orb., 1846, Bass. tert. Vienne, p. 233, Pl. XIII. Figs. 1–3.
P. ovata Br., 1884, Chall. Rep., IX. p. 564, Pl. LXXII. Figs. 7, 8.

The typical *ovata* of d'Orbigny has in its arrangement of the segments something in common with the *compressa* of the same author; but the *ovata* of Brady differs from both in having the last two segments somewhat larger than in the type. At any rate Brady's representation of this form perfectly agrees with our only specimen from the Pacific.

Pacific. 885 fathoms; rare.

CRISTELLARIA Lamarck.

C. rotulata Lmck.

Lenticulites rotulata Lmck. (1804), 1830, Encycl. Méth. Vers., Pl. 466, Fig. 5.
Nodosarina calcar Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 49, Pl. III. Figs. 57–59 (*cultrata*), 60, 61 (monstrous).
C. rotulata Br., 1884, Chall. Rep., IX. p. 347, Pl. LXIX. Fig. 13.
C. rotulata Goës, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 59, Pl. X. Figs. 559–578.

This species attains a high development in the tropical seas, where it affects depths of 200–1500 fathoms. Specimens from the Pacific have some tendency to sutural limbation, and the keel of the margin is often somewhat thickened. Such forms may be referred to *Robul. ornata* d'Orb., but it is impossible to assign to such fickle features any specific importance. Between the forma *cultrata* Mtfrt. and the type no definite boundary line can be traced.

Pacific. 660–1201 fathoms.
Caribbean Sea. 68–1600 fathoms.

Allied Forms: —

1. **C. calcar** Lin.

Nautilus calcar Lin. (partly), 1758, Syst. Naturæ, ed. X. p. 709.
Nodosarina calcar Goës (partly), 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. III. Figs. 54–56.
Cristellaria calcar Br., 1884, Chall. Rep., p. 551, Pl. LXX. Figs. 9–15.

The rowelled form of the type is not so common as this itself, although in the Caribbean Sea it is pretty often met with. The form with deeply serrated marginal wing is an intermediate form between *cultrata* and *calcar*.

Caribbean Sea. 25–420 fathoms.

2. C. vortex Ficht. & Moll.

Nautilus vortex Ficht. & Moll., 1803, Test. Micr., p. 33, Pl. II. Figs. *d–i*.
C. vortex, orbicularis, Br., Chall. Rep., IX. pp. 548, Pl. LXIX. Figs. 14–17.

Differs from the type only by its narrower and more bent chambers.

Robul. orbicularis, imperatoria, and *Soldanii* d'Orb., cannot reasonably be differentiated from this form.

Caribbean Sea. 130 fathoms ; scarce.

C. gibba d'Orb.

C. spectabilis Reuss, Deutsch. Septarienthon, Wien. Ak. Dkschr., XXV., p. 141, Pl. III. Figs. 9, 10.
C. gibba d'Orb., 1839, For. Cuba, p. 40, Pl. VII. Figs. 20, 21.
C. galeata Reuss, 1851, Septar. Thon. Berlin (partly), Zeitschr. deut. geol. Gesellsch., p. 66, Pl. IV. Fig. 20.
C. gibba Br., 1884, Chall. Rep., IX. p. 546, Pl. LXIX. Figs. 8, 9.
C. gibba Goës, 1894, Sv. Vet. Ak. Hdl., XXV. 9, p. 61, Pl. X. Figs. 587–592 (*alata* passing into *C. nitida* d'Orb.).

The more oval form of *C. rotulata*, with the last segment somewhat produced, seems to be a link between the type and *C. crepidula* Ficht. & Moll. It is sometimes more flattened and has often received new names.

Pacific. 1132 fathoms ; scarce.

Caribbean Sea. 210 fathoms ; scarce.

C. cassis var. marginata d'Orb.

Plate V. Figs. 13, 14.

It is by no means easy to give a natural and true systematic review of all the lineate, papillate, or beaded, and at the same time of the cultrate and rowelled forms of Cristellaria, the beads and their distribution over the shell surface, and of the lines yielding such fickle characteristics that they cannot prove as satisfactory for a specific or subspecific determination. According to the different authors a scheme for such a review should assume this appearance : —

I. Neither lineolate nor costate forms :

A. No beads : = *C. calcar* Lin. (partly), *Nautil. calcar* Ficht. & Moll., 1803, var. *a*, *θ*, *κ*, *μ*, Pl. XI. Figs. *a–c*, Pl. XII. Figs. *i*, *k*, Pl. XIII. Figs. *c*, *d*, *h*, *i* ; *Rob. calcar* d'Orb., 1846, Bass. tert. Vienne, p. 99, Pl. IV. Figs. 18–20 ; *Rob. aculeata, radiata, pulchella, rosacea, rotunda, lævigata* d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. pp. 288–290.

B. Beaded.

a. Sutures and sometimes the centrum beaded : *Naut. calcar* var. *γ*, *δ*, *ι* Ficht. & Moll., 1803, Pl. XI. Figs. *g–k*, Pl. XIII. Figs. *a*, *b* ; *Naut. papillosus*, F. & M., 1803, Pl. XIV. Figs. *a–c* ; Brady, 1884, Chall. Rep., IX. p. 553, Pl. LXX. Fig. 16 ; *Crist. papillosa* Fornasini, 1894, For. Marne Messinesi, Mem. R. Acc. Sc. Istituto Bologna (5.), IV. Pl. III. Figs. 29–32 ; *Rob. gutticostata* Gümb., 1868, Nordalp. Eocän, K.

Bayr. Wiss. Akad., Abh. X. Pl. I. Fig. 74; HANTK., 1875, Clav. Szab. Sch., Pl. VI. Fig. 10; *Cr. mamillegera* KARR., 1865, Novara Exp., Geol., Th., Pl. XVI. Fig. 5; BRADY, 1884, Chall. Exp., IX. Pl. LXX. Figs. 17, 18; *Naut. cassis* F. & M., 1803, Pl. XVII. Fig. *f*, etc.

b. Sutures smooth, segments wholly or partly beaded: *Naut. calcar* var. *e* F. & M., Pl. XII. Figs. *a–c*; *Rob. calcar, tuberculata, elegans* D'ORB., 1826, An. Sc. Nat., VII. pp. 289, 292, 293; *Crist. erinacea* KARR., 1878, For. Luzon, Bol. Mapa Geol. Espan., VII. p. 19, Pl. F, Fig. 3.

c. Sutures and segments beaded: *Crist. aculeata* D'ORB., 1826, Tab. Méth., An. Sc. Nat., VII. p. 292; BRADY, Chall. Rep., IX. p. 555, Pl. LXXI. Figs. 4, 5; *C. papillosa* D'ORB., Ibid., p. 293; *C. marginata* D'ORB., Ibid., p. 291; *Rob. granulata* HKN., 1875, Clav. Szab. Sch., p. 57, Pl. XIV. Fig. 15; *C. echinata* BR., Chall. Rep., p. 554, Pl. LXXI. Figs. 1–3.

II. Lineolate or costate rowelled forms.

A. no beads or prickles: = *Rob. echinata* CZJZ., 1847, For. Wien. Beck., Haid. Nat. Wiss., Abh. II. p. 141, Pl. XII. Figs. 24, 25; *Rob. vaticana* COSTA, 1855, Marna, Vatic. Mem. Nap., II. p. 122, Pl. I. Fig. 17.

B. Segments beaded: *Rob. echinata* D'ORB., 1846, Bass. tert. Vienne, p. 100, Pl. IV. Figs. 21, 22.

At present our materials of these forms are too scantily represented to enable us to make up a true relationship between them, but so much could now be suggested that the beaded forms could possibly be included under 4 or 5 varieties, the most of them under the head of *C. rotulata* and *cassis*, the disposition of the beads over the surface not being taken into account as of smaller distinguishing value. *Crist. marginata* D'ORB. has some tendency to assume an oval *cassis*-like form, and the often emarginated keel or wing will be reduced to strong marginal spines. Such a form is represented in my paper on the Ret. Rhizop. of the Caribbean Sea, Sv. Vet. Ak. Hdl., 1882, XIX. 4, Pl. III. Figs. 50, 51, with limbated and beaded septa, and the segments also partly beaded, the riper segments being more or less smooth. The semicircular anterior bordering of the top segment cannot be considered as a differential characteristic. The mouth is often pouting in the top of the last segment.

The beads are often small, scanty, and sometimes nearly obsolete. The difference between *C. marginata* and *C. aculeata* BR. is more limited than at first sight will be observed. It attains a length of 3–5 mm.

Caribbean Sea. 196–210 fathoms; scarce.

C. aculeata D'ORB., var. marginulinoides GOËS.

Plate V. Figs. 15, 16.

C. aculeata D'ORB., 1826, Tab. Méth., An. Sc. Nat., VII. p. 292 (type).
C. aculeata BR., 1884, Chall. Rep., IX. p. 555, Pl. LXXI. Figs. 4, 5.
GUPPY, 1894, For. Trinidad, Proceed. Zoöl. Soc. London, Nov. 6, 1894, Pl. XLI. Fig. 2.
?*Marg. aculeata* NEUGEBOR, 1851, For. Lapugy, Siebenburg. Ver. Mittheil., II. Pl. IV. Fig. 21.

? *Cr. spinulosa* KARR., 1877, Abh. Geol. Reichsanst. Oesterr., IX. Pl. XVI. Fig. 34.
? *Marg. cristellarioides* FORNAS., 1893, Mem. R. Ac. Sc. Istit. Bologna (5.), IV. Pl. II. Fig. 16.

In the outlines the West Indian form is rather Marginulina-like, with strong raised and often beaded septa, sometimes the beads growing to short spines, particularly on the early segments, which often are carinate and their margins provided with spines. Our form seems to have narrower and more closely fitted chambers than the specimens designed by Brady. Length about 2.30 mm.

Caribbean Sea. 200 fathoms.

ALLIED FORM:—

C. ensiformis GOËS.

The representation on our Plate V. Figs. 17, 18, is a more seldom met with smooth variety, with quite Marginulina-formed outlines, resembling *Marg. ensis* REUSS, its close affinity to *C. aculeata* shown only by intermediate forms and the marginal spines of the early stage, those spines being sometimes nearly obsolete. Length about 3 mm.

Caribbean Sea. 196–210 fathoms.

C. crepidula FICHT. & MOLL.

Nautil. crepidula FICHT. & MOLL., 1803, Test. Micr., p. 107, Pl. XIX. Figs. *g*, *i*.
Nodosarina crepidula GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 43, Pl. II. Fig. 44, Pl. III. Figs. 36–42.
C. crepidula BR., 1884, Chall. Rep., IX. p. 542, Pl. LXVII. Figs. 17, 19, 20, Pl. LXVIII. Figs. 1, 2.
C. crepidula GOËS, 1893, Sv. Vet. Ak. Hdl., XXV. 9, p. 62, Pl. XI. Figs. 596–613.

This form is not very rare in moderate depths of the tropic seas, although it has been scantily met with in "Albatross" dredgings. It assumes a lot of varietal forms, being impossible to define it on one side from *Vaginulina lævigata* ROEM., and on the other from *C. rotulata* LMCK.

Pacific. 1132–1201 fathoms.

Caribbean Sea. 200–400 fathoms (Goës).

ALLIED FORM: —

C. subarcuatula MONTAGU. Plate V. Figs. 19–24.

Nautilus subarcuatulus MONTAGU, 1808, Test. Brit., Supplem., p. 80, Pl. XIX. Fig. 1 (limbate).
C. subarcuatula WILLIAMS., 1858, Rec. For. Gr. Brit., Pl. II. Fig. 62.
C. calcar forma *marginulinæ* PARK. & JONES, 1857, For. Coast of Norway, An. Mag. Nat. Hist. (2.), XIX. p. 269, Pl. X. Fig. 1.
Marg. lituus PARK. & JONES, 1865, North Atl. & Arct. Oc., Phil. Transact., CLV. p. 343, Pl. XIII. Fig. 14.
C. obtusata var. *subalata* BR., 1884, Chall. Rep., IX. p. 536, Pl. LXVI. Figs. 24, 25.
C. subarcuatula GOËS, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 63, Pl. XI. Figs. 630–637.

In his synopsis of the British Recent Foraminifera, 1887, Journ. R. Microsc. Soc., 1887, (2.), VII. p. 911, Brady has used the name of *elongata*, but that epithet was long ago bestowed by d'Orbigny on a winged and broader form of *crepidula*. Brady considers this form also to be nearly identical with *C. obtusata* of Reuss, but that form has its allies amongst a set of Cristellariæ peculiar to earlier tertiary horizons, distinguished by their tumid segments.

Sometimes it has the sutures strongly limbated, a fine specimen of that feature having been met with amongst ordinary samples in the Caribbean Sea. Montagu has also represented his *subarcuatula* with limbated sutures. The specimens met with in the Pacific are very slender, and approach in appearance *Vaginulina lævigata* Roem.

Pacific. 885–1201 fathoms.

Caribbean Sea. 347–420 fathoms.

C. italica Defr.

Saracenaria italica Defr., 1824, Atlas Conch., Pl. XIII. Fig. 6.
Nodosarina crepidula var. *italica* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 47, Pl. III. Figs. 45–49.
C. italica Br., Chall. Rep., IX. p. 544, Pl. LXVIII. Figs. 17, 18, 20–23.

This is an easily distinguished form, when in a certain state of development, but sometimes forms are met with which can hardly be distinguished from thick *Marginulinæ* or from some varieties of *C. crepidula*. Sometimes it develops itself in a prolonged row of segments attaining a length of 8 mm.

Caribbean Sea. 169–658 fathoms; not scarce.

C. variabilis Reuss.

C. variabilis Reuss, 1849, Neue For. Oesterr., Wien. Ak. Dkschr., I. p. 369, Pl. XLVI. Figs. 15, 16.
C. variabilis Br., 1884, Chall. Rep., IX. p. 541, Pl. LXVIII. Figs. 11–16.
C. variabilis Goës, 1893, Sv. Vet. Ak. Hdl., XXV. 9, p. 62, Pl. X. Figs. 593–595.

A small, usually more or less compressed form, that sometimes assumes a Marginulina-formed, elongated shape, owing to the later segments' arrangement in a straight or nearly straight way. It is often carinated.

Caribbean Sea. 420 fathoms; scarce.

VAGINULINA d'Orb.

V. lævigata Roem.

V. lævigata Roem., 1838, Nordl. tert. Meeress., Leonh. & Bronn., Jhb. 1839, p. 383, Pl. III. Fig. 11.
V. legumen Br., 1884, Chall. Rep., IX. p. 530, Pl. LXVI. Figs. 14, 15.
V. lævigata Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9. p. 65, Pl. XI. Figs. 646-655.

This form is by no means common in the tropical seas, and specimens of strong growth are seldom met with. It is often of pygmy size, 0.50–1.50 mm.

Caribbean Sea. 196–463 fathoms.

ALLIED FORM:—

V. glabra D'ORB.

Marginulina glabra D'ORB., 1826, An. Sc. Nat., VII. p. 259, No. 6, Mod. 55.
Marginulina glabra BR., 1884, Chall. Rep., IX. p. 527, Pl. LXV. Figs. 5, 6.
Marginulina glabra GOËS, 1894, Arct. & Scand. Foramf., Sv. Vet. Akad. Hdl., XXV. 9, p. 65, Pl. XI. Figs. 656–661 (slender and inflated forms).

There is not the slightest ground for assigning this form to a separate genus, as d'Orbigny has done, for it is very closely allied to *V. lævigata*. It varies from broad and short form to more elongate and slender; usually it is more or less compressed, but often nearly cylindric; sometimes the segments are much inflated.

Pacific. 1132 fathoms.

Caribbean Sea. 382–789 fathoms.

V. linearis, MONTAGU.

Nautilus linearis MONTAGU, 1808, Test. Brit., Supplem., p. 87, Pl. XXX. Fig. 9.
V. linearis BR., 1884, Chall. Rep., IX. p. 532, Pl. LXVII. Figs. 10–12.
V. linearis GOËS, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak., XXV. 9, p. 66, Pl. XII. Fig. 664.

Of this two closely allied forms are met with in the Caribbean Sea; the one resembles perfectly the type, only being perhaps more cylindric in the circumference, the other is often somewhat compressed and may be referred to the variety *striato-costata* of Reuss; the former is represented in my paper on Ret. Rhizop. of Caribbean Sea, Sv. Vet. Akad. Hdl., XIX. 4, Pl. II. Fig. 32; the latter, Fig. 33, and in Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, Pl. XII. Fig. 665.

Both forms in Caribbean Sea. 45–300 fathoms; scarce.

NODOSARIA LAMARCK.

N. lævigata D'ORB.

Glandulina lævigata D'ORB., 1826, Tabl. Méth., An. Sc. Nat., VII. p. 252, Pl. X. Figs. 1–3.
N. lævigata BR., 1884, Chall. Rep., IX. p. 490, Pl. LXI. Figs. 20–22.
N. lævigata GOËS, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 71, Pl. XIII. Figs. 702, 703, 706, 707.

The typical apiculate *Glandulina lævigata* is the prevalent form of this group in moderate depths of tropic seas, where it attains a high development.

Pacific. 770–1132 fathoms; large.

Caribbean Sea. 382–789 fathoms.

N. radicula Lin.

Naut. radicula Lin., 1758, Syst. Naturæ, ed. X. p. 711.
Nod. radicula d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 252, Mod. 1 (*N. solutæ* Reuss *proxima*).
Nod. radicula Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 10, Pl. I. Figs 1, ? 2.
Nod. radicula Br., 1884, Chall. Rep., IX. p. 495, Pl. LXI. Figs. 28–31 (*glandulinaformis*).

Owing to its great variability in its ovoid-cylindric shape, in its either slender or stout growth, in the degree of constriction of the sutures, and in the relative length of the segments, it will be nearly impossible to trace a distinct boundary line between *N. radicula* and *N. lævigata* on one side, and *N. soluta* Reuss on the other. Such forms as *Gland. rotundata* Bornem., *Gland. mutabilis* (partially) Reuss are intermediate forms between *N. radicula* and *lævigata;* and *N. radicula* d'Orb. (Mod. 1), with deep sutural constrictions and globular segments, is not distinguishable from *N. soluta* and *N. Geinitzi* Reuss, which can with difficulty be distinguished from *N. glabra* d'Orb. In his valuable paper on Nodosarie Terziarie del Piemonte, 1894, Bull. Soc. Geol. Ital., XII. (1893), fasc. 4, Rev. E. Dervieux has pointed out five varieties of this species.

Naut. radicula Montagu, Test. Brit., 1803, was by English rhizopodologists once suspected to represent a *Clavulina*, but in Chall. Rep., IX., Brady has identified it with *N. radicula*. About fifty different denominations have been bestowed on this form by authors.

Pacific. 1201 fathoms; rare; slender form.

Caribbean Sea. 120 fathoms; rare; stout.

N. comata Batsch.

Nautilus comatus Batsch, 1791, Conchyl. Seesandes, Pl. I. Fig. 2, *a–d*.
Nod. (*Glandulina*) *glans* d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 252, No. 2, Mod. 51.
? *Nod. radicula* var. *Raphanus* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. I. Figs. 9, 10 (extenuated form).
Nod. comata Br., 1884, Chall. Rep., IX. p. 509, Pl. LXIV. Fig. 1–5 (stout forms).

This handsome species has not been met with by the "Albatross," but it occurs sparingly in the Caribbean Sea at moderate depths. Small and extenuated samples merge into *N. scalaris* Batsch.

Caribbean Sea. 300–400 fathoms (Goës).

Allied Form:—

N. scalaris Batsch.

Nautilus scalaris Batsch, 1791, Conchyl. Seesandes, Pl. II. Fig. 4.
Nod. radicula var. *scalaris* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 21, Pl. I. Fig. 8.

Nod. scalaris Br., 1884, Chall. Rep., IX. p. 510, Pl. LXIII. Figs. 28–31, Pl. LXIV. Figs. 16–19.

Nod. scalaris Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 73, Pl. XIII. Figs. 716–718.

An extenuated pygmy form of the type.

Caribbean Sea. Not very scarce at 300–400 fathoms (Goës).

N. communis d'Orb.

Plate VI. Fig. 1.

Dental. communis d'Orb., 1840, Craie bl. Paris, Mém. Soc. Géol. Fr., IV. p. 13, Pl. I. Fig. 4.

Dental. inornata, badenensis d'Orb, 1846, Bass. tert. Vienne, p. 44, Pl. I. Figs. 48–51.

Nodos. communis Goës, 1882, Ret. Rhizop. Caribbean Sea, Sv. Vet. Ak. Hdl., XIX. Pl. I. Fig. 16, Pl. II. Figs. 22, 24, 25 (assigned to *Vaginulina legumen*, while somewhat compressed).

Nodos. Roemeri Neug., 1856, Stichosteg. Ober-Lapugy, Wien. Ak. Dkschr., XII. p. 82, Pl. II. Figs. 13–17 (short form).

Nodos. communis, roemeri Br., 1884, Chall. Rep., IX. pp. 504, 505, Pl. LXII. Figs. 19–22, Pl. LXIII. Fig. 1.

Nodos. communis Goës, 1894, Sv. Vet. Ak. Hdl., XXV. 9, p. 68, Pl. XII. Figs. 667–671.

The name of *communis* was conferred in 1840 by d'Orbigny on a slender Nodosarina with obliquely set septa from the chalk of Paris; but a short time afterwards, in 1846, new names, as *badenensis*, *inornata*, were given to the same form. Previously, 1826, d'Orbigny had bestowed the name *communis* on Soldani's form *farcimen*.

As this denomination of Soldani should take precedence, it would be unnecessary to discard d'Orbigny's name for the form described in 1840, as some authors have proposed, and change it for its later synonym, *inornata*. It cannot be well distinguished from *N. Roemeri* and *N. mucronata* (Neug.) Brady

Pacific. 1132–1839 fathoms.

Carribbean Sea. 130–1832 fathoms; not common.

N. pauperata d'Orb.

Dental. pauperata d'Orb., 1846, Bass. tert. Vienne, p. 46, Pl. I. Figs. 57, 58 (with larger initial segment).

Nodos. pauperata Br., 1884, Chall. Rep., IX. p. 500 (woodcut).

Nodos pauperata Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 68, Pl. XII. Figs. 672–686.

This form acquires in tropic seas, particularly in the Caribbean Sea, a high development of comparatively gigantic dimensions. It has been loaded with different names. The riper segments have a tendency to become inflated with constricted sutures, and it is this feature together with the different relative

size of the transverse diameter, arising mostly from the size of the initial or embryonal segment, that create a lot of variations.

Pacific. 978, 1740 fathoms; scarce and starved.

Caribbean Sea. 100–400 fathoms; not scarce (Goës).

Allied Form:—

N. Boueana d'Orb. Plate VI. Fig. 2.

Dental. Boueana d'Orb., 1846, Bass. tert. Vienne, p. 47, Pl. II. Figs. 4–6.
Nodos. communis var. Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. I. Figs. 13, 14, 15.
Nodos. filiformis Br., 1884 (partly), Chall. Rep., IX. p. 500, Pl. LXIII. Fig. 3.
Nodos. Boueana Goës, 1894, Sv. Vet. Ak. Hdl., XXV. 9, p. 69, Pl. XII. Fig. 689.

A very attenuated form, with long and narrow elliptic or cylindric segments and more or less constricted sutures. *Nodos. ovicula* d'Orb. is to be considered as a riper form of *Boueana*.

From *Dental. filiformis* d'Orb. it is faintly distinct, by its longer and not globular segments. But it very often happens that the young stage of *Boueana* is provided with quite globular segments, and the mature part of the same colony with long-ovoid ones, 2–3 times longer than broad. From *Orthoceras farcimen* (= *Dentalina communis* d'Orb., 1826) it is hardly distinguishable, although that form should have somewhat shorter and wider segments.

Caribbean Sea. 65–200 fathoms.

N. soluta Reuss.

Dental. soluta Reuss, 1851, Septar. Thon Berlin, Ztschr. deut. geol. Gesellsch., III. p. 60, Pl. III. Fig. 4 (nearly identical with *pyrula* d'Orb.).
Dental. soluta Reuss, 1866, Deutsch. Septarienth., Wien. Ak. Dkschr., XXV. p. 131, Pl. II. Figs. 4–8.
N. soluta Br., 1884, Chall. Rep., IX. p. 503, Pl. LXII. Figs. 13–16.
N. soluta Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 70, Pl. XII. Fig. 690.

This form is sometimes hardly distinguished from *N. pauperata*, of which it may be a megalasphæric offspring on one side, and from *N. pyrula* on the other. Some of the specimens designed by Reuss as *soluta* seem to be very close to *pyrula* by having some traces of segmental necks.

Pacific. 995–1201 fathoms.

Caribbean Sea. 169–821 fathoms.

N. monile Sold.

Nodos. radicula var. *monile* Goës, 1882, Ret. Rhizop. Caribbean Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 15, Pl. I. Figs. 3–6.
Nod. pyrula Br., 1884, Chall. Rep., IX. p. 497, Pl. LXII. Figs. 10–12.

The form designed by Soldani as *Orthoceras monile* has globular segments, but in other respects it differs nothing from *pyrula* D'ORB., which is provided with ovoid or pyriform segments. The form of Soldani seems to be seldom met with in recent condition. Soldani's name should take precedence of *Nod. pyrula* D'ORB., 1826, Tab. Méth., An. Sc. Nat., VII. p. 253, No. 13.

Pacific. 885–1201 fathoms; not common.

Caribbean Sea. 196–210 fathoms; not common.

ALLIED FORM:—

N. hispida (SOLDANI) D'ORB.

N. hispida D'ORB., 1846, Bass. tert. Vienne, p. 35, Pl. I. Figs. 24, 25.
N. hispida BR., 1884, Chall. Rep., IX. p. 507, Pl. LXIII. Figs. 12–16.

Closely allied to *N. monile*, and differs from that only in having its globular segments beset with pseudopodial spines or tubes, and the two or three earliest segments usually without necks.

Caribbean Sea. 196–387 fathoms; not common.

N. obliqua LIN.

Nautilus obliquus LIN., 1758, Syst. Nat., ed. X. p. 710.
Nodos. obliqua GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. I. Fig. 18 (*vertebralis*).
N. obliqua BR., 1884, Chall. Rep., IX. p. 513, Pl. LXIV. Figs. 20–22.
N. vertebralis BR., Ibid., Pl. LXIV. Figs. 11–13.
N. obliqua GOËS, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 70, Pl. XII. Figs. 691–696, Pl. XIII. Figs. 697–699 (*vertebralis*).
FORNASINI, 1892, R. Accad. Sc. Istit. Bologna (5.), Pl. I. Figs. 1–7.

N. obliqua and its quasi variety *vertebralis* BATSCH come to high development in these seas, particularly in the Caribbean Sea.

I retain Linné's name for this form, as most authors have done, although it originally was probably intended for an obliquely lineated or costate form by Batsch designated by the name *Naut. obliquatus*.

Pacific. 885–1132 fathoms.

Caribbean Sea. 68–1181 fathoms.

ALLIED FORM:—

N. raphanistrum var. obsoleta GOËS. PLATE VI. Fig. 3.

This can scarcely be considered as anything else than a highly developed form of the preceding. It may be put in question if this giant form may not be identical with the tertiarian *N. raphanistrum* LIN., from which it differs only in having the ribs or lineation not so strongly marked, sometimes nearly obsolete even on earlier segments.

From *Nod. bacillum* DEFR., Atlas Conch., Pl. XIII. Fig. 4, it also differs in this respect only.

Cf. also *Nod. raphanistrum* SILVESTRI, 1872, Fauna Micros. Terr. subapenn. Italiano, Atti Acc. Gioenia Sc. Nat. Catan. (3.), VII. p. 27, Pl. I. Figs. 1–25.

Caribbean Sea. 227–332 fathoms; scarce.

N. seminuda REUSS.

Plate VI. Figs. 4, 5.

Dental. seminuda REUSS, 1849, Neue For. Oesterr., Wien. Ak. Dkschr., I. p. 367, Pl. XLVI. Fig. 9.

Nod. obliqua var. GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. I. Fig. 17.

Nod. seminuda GOËS, 1894, Sv. Vet. Ak. Hdl., XXV. 9, p. 71, Pl. XIII. Fig. 700.

An interesting form, giving a hint about the origin of the smooth forms of Nodosarina, particularly of *N. pauperata* D'ORB., of which it should be considered as an allied form. It attains large dimensions, 17–22 mm. in length. The septa are somewhat thickened, but not exactly limbate in our form.

Caribbean Sea. 300 fathoms (Goës).

N. striolata GOËS.

Plate VI. Figs. 6, 7.

N. striolata GOËS, 1894, Sv. Vet. Ak. Hdl., XXV. 9, p. 71, Pl. XIII. Fig. 701.
N. soluta BR., 1884, Chall. Rep., IX. Pl. LXIV. Fig. 28.
? *Dental. substriata* D'ORB., 1826, Tab. Méth., An. Sc. Nat., VII. p. 255, No. 46.

In the form and arrangement of the segments it differs very little from *N. soluta* REUSS; the surface is very faintly striated, but the naturer segments are more or less smooth.

Caribbean Sea. 300 fathoms; scarce (Goës).

N. raphanus LIN.

Naut. raphanus LIN., 1758, Syst. Nat., ed. X. p. 711.
Nod. raphanus BR., 1884, Chall. Rep., IX. p. 512, Pl. LXIV. Figs. 6–10.

Only a single specimen in a pygmy condition has been met with; it has a prismatic conical form, with few and broad ribs.

Pacific. 695 fathoms; scarce.

RHABDOGONIUM REUSS.

R. tricarinatum D'ORB.

Vaginulina tricarinata D'ORB., 1826, An. Sc. Nat., VII. p. 258, No. 4, Mod. 4.
Rhabdogonium tricarinatum BR., 1884, Chall. Rep., IX. p. 525, Pl. LXVII. Figs. 1–3.

Seems to be very rare in the course of the "Albatross" cruise, a couple of specimens only having occurred in the Pacific. In comparison with specimens from tertiary deposits the recent form is usually a pygmy.

Pacific. 730 fathoms; scarce.

LINGULINA d'Orb.

L. carinata d'Orb.

L. carinata d'Orb., 1826, An. Sc. Nat., VII. p. 257, Mod. 26.
Nodosarina carinata Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 58, Pl. I. Figs. 65, 66; Fig. 67 (*seminuda*).
L. carinata Br., 1884, Chall. Rep., IX. p. 517, Pl. LXV. Figs. 16, 17.

In moderate depths of Caribbean Sea and the Gulf of Mexico this species attains good sized proportions and is not very scarce. Both the smooth and semilineated forms are met with.

Caribbean Sea. 25–533 fathoms; not very scarce.

FRONDICULARIA Defr.

F. alata d'Orb.

F. alata d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 256, No. 2.
F. complanata var. *alata* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 56, Pl. III. Figs. 62–64.
F. complanata var. *alata* Dervieux, 1893, Frond. terz. Piemonte, Atti R. Accad. Lincei, p. 238, Pl. IV. Figs. 6, 9, 10–12.
F. alata Br., 1882, Chall. Rep., IX. p. 522, Pl. LXV. Figs. 20–23.

This well known species is not scarce in certain localities in the Caribbean Sea, and reaches there pretty large dimensions. It is worthy of notice that flabelline forms of this species are usually less frequent than the more advanced Frondicularia form, inferring that the older type is on its way to extinction from the recent fauna.

Caribbean Sea. 200–300 fathoms (Goës).

GLOBIGERINA d'Orb.

G. bulloides d'Orb.

G. bulloides d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 277, No. 1, Mod. 17, 76.
G. bulloides Br., 1894, Chall. Rep., IX. p. 593, Pl. LXXIX. Figs. 1–7.
G. bulloides Goës, 1893, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 83, Pl. XIV. Figs. 754–762.

This 3–4-segmented form of *Globigerina* seems not always in tropical seas to be the chief constituent of what is called Globigerina ooze. In fact, the forms *G. sacculifera*, *conglobata*, and in the Pacific *dubia* (Egger) Br., are most frequent. In some places also *G. rubra* is very prominent. *Orbulina*, that is, a ripe embryo segment of various forms of *Globigerina*, accompanies these in great abundance.

On both sides of the Isthmus. Pelagic.

ALLIED FORMS: —

1. G. sacculifera BRADY.

G. sacculifera BR. (1879), 1884, Chall. Rep., IX. p. 604, Pl. LXXX. Figs. 11–17, Pl. LXXXII. Fig. 4.
G. bulloides var. GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. VI. Figs. 197–200.

A very variable form. The last segment is sometimes not produced in length, but only compressed. Usually the segments are more loosely coherent than in the type.

Pelagic on both sides of the Isthmus.

2. G. dubia (EGGER) BRADY.

G. dubia (EGGER, 1857) BR. (1879), 1884, Chall. Rep., IX. p. 595, Pl. LXXIX. Fig. 17.

A more regular rotaliform variety, and probably a more developed form of *G. cretacea* D'ORB., with 5–7 inflated segments in the outer convolution and a deep umbilical vestibule.

The stout form seems to have its main abode in the Pacific, while the pygmy form (*G. cretacea* D'ORB.) is prevalent in the Caribbean Sea.

3. G. æquilateralis BRADY.

G. bulloides var. GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. VI. Figs. 201, 202.
G. æquilateralis BR. (1879), 1884, Chall. Rep., IX. p. 605, Pl. LXXX. Figs. 18–21.
G. æquilateralis GOËS, 1874, Sv. Vet. Ak. Hdl., XXV. 9, p. 86, Pl. XIV. Fig. 767.

Mostly planospiral in the arrangement of its few chambers; often the last whorl constitutes an open detached spiral, but at other times it is quite closely attached to the preceding one.

On both sides of the Isthmus. Pelagic.

4. G. conglobata BRADY.

G. conglobata BR. (1879), 1884, Chall. Rep., IX. p. 603, Pl. LXXX. Figs. 1–5; Pl. LXXXII. Fig. 5.
G. bulloides var. GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. VI. Fig. 196.
G. bulloides GOËS, 1894, Sv. Vet. Ak. Hdl., XXV. 9, p. 86, Pl. XIV. Figs. 768, 769.

Seems to be a riper form of the type; the arrangement of the chambers is subject to some variability; the sutural apertures of the spire are no constant feature.

Both sides of the Isthmus.

5. G. rubra d'Orb.

G. rubra d'Orb., 1839, For. Cuba, p. 82, Pl. IV. Figs. 12–14.
G. rubra Br. (1879), 1884, Chall. Rep., IX. p. 602, Pl. LXXIX. Figs. 11–16.
G. rubra Goës, 1874, Sv. Vet. Ak. Hdl., XXV. 9, p. 85, Pl. XIV. Fig. 766.

A trifling variety of the type, with three segments in the outer convolution, somewhat elevated spire, and often with additional apertures in its sutures; the color is often pink, but not unfrequently colorless samples are met with. The extreme height of the spire, exhibited in Brady's Chall. Rep., is not a common feature.

Caribbean Sea. Not rare.

HASTIGERINA Wyville Thomson.

H. pelagica d'Orb.

Nonionina pelagica d'Orb., 1839, Voy. Am. Mérid., V. p. 27, Pl. III. Figs. 13, 14.
H. Murrayi Wyv. Thomson, 1876, Rep. from Challeng., Proc. Roy. Soc., XXIV. p. 534, Pl. XXII., XXIII.
H. pelagica Br. (1879), 1884, Chall. Rep., IX. p. 613, Pl. LXXXIII. Figs. 1–8.

A few much decayed specimens have been met with.

Caribbean Sea. 210–724 fathoms; pelagic.

SPHÆROIDINA d'Orb.

S. bulloides d'Orb.

S. bulloides d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 267, No. 1, Mod. 65.
S. bulloides Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 89, Pl. VI. Figs. 190–193.
S. bulloides Br., Chall. Rep., XIX. p. 620, Pl. LXXXIV. Figs. 1–7.
S. bulloides Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 87, Pl. XIV. Fig. 770.

Attains high development in tropical seas, specimens of 1 mm. in diameter being common. The middle-sized individuals are probably pelagic.

Pacific. 885–1132 fathoms.

Caribbean Sea. 300–800 fathoms.

S. dehiscens Park. & Jones.

S. dehiscens Park. & Jones, 1865, Philos. Transact., CLV. Pl. XIX. Fig. 5 (the apertures larger than usual).
Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., Pl. VI. Fig. 195.
S. dehiscens Br. (1879), 1884, Chall. Rep., IX. p. 621, Pl. LXXXIV. Figs. 8–11.

Is just as much related to Globigerina as to Sphæroidina, both on account of the arrangement of the apertures, the trilobated set of the globular segments, and the coarse poration.

Pacific. 770–1322 fathoms; not scarce.

Caribbean Sea. 169–1946 fathoms; perhaps also pelagic.

CANDEINA d'Orb.

C. nitida d'Orb.

C. nitida d'Orb., 1839, For. Cuba, p. 111, Pl. II. Figs. 27, 28.
C. nitida Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 89, Pl. VI. Figs. 187–189.
C. nitida Br. (1879), 1884, Chall. Rep., IX. 622, Pl. LXXXII. Figs. 13–20.

This pretty pelagic form has been met with in the Caribbean Sea only.

PULLENIA Park. & Jones.

P. obliqueloculata Park. & Jones

P. obliqueloculata, Park. & Jones (1862), 1865, North Atl. & Arct. Oceans, Philos. Trans., CLV. p. 368, Pl. XIX. Fig. 4.
P. obliqueloculata Br., 1884, Chall. Rep., IX. p. 618, Pl. LXXXIV. Figs. 16–20.

Is sometimes hardly distinguishable from *P. sphæroides* d'Orb., the chief characteristics being its slight inequilateral growth, somewhat obliquely set mouth, and usually stouter build, together with the slight lobation of the circumference; but sometimes all these features are very faintly marked.

On both sides of Isthmus. Probably pelagic.

P. quinqueloba Reuss.

Nonionina quinqueloba Reuss, 1851, Septar. Thon Berlin, Zeitschr. deut. geol. Gesellsch., III. p. 72, Pl. V. Fig. 31.
P. sphæroides var. Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. VIII. Figs. 248, 249.
P. quinqueloba Goës, 1874, Arct. & Scand. Foramf., Sv. Vt. Ak. Hdl., XXV. 9, p. 87, Pl. XIV. Fig. 773.
P. quinqueloba Br., 1884, Chall. Rep., IX. p. 617, Pl. LXXXIV. Figs. 14, 15.

This variety of *P. sphæroides* d'Orb. has been met with, but is very scarce; it has sometimes 4 segments only.

Pacific. 1100–1200 fathoms; scarce.

Caribbean Sea. 250–300 fathoms (Goës).

P. sphæroides D'ORB.

Nonionina sphæroides D'ORB., 1826, Tab. Meth., An. Sc. Nat., VII. p. 293, No. 1, Mod. 43.
Pullenia sphæroides GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 104, Pl. VIII. Fig. 250.
P. sphæroides BR., 1884, Chall. Rep., IX. p. 615, Pl. LXXXIV. Figs. 12, 13.
P. sphæroides GOËS, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 87, Pl. XIV. Figs. 771, 772.

Is not so common as the irregular form *obliqueloculata*.
Caribbean Sea. 300 fathoms (Goës).

DISCORBINA PARK. & JONES.

D. orbicularis (TERQU.) BRADY.

D. orbicularis BR., 1884, Chall. Rep., IX. p. 647, Pl. LXXXVIII. Figs. 4–8.
D. rosacea GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 105, Pl. VIII. Figs. 251–257.

This pygmy form is nothing else than a modification of *D. rosacea* D'ORB. It is not uncommon in moderate depths.
Caribbean Sea. 300 fathoms (Goës).

D. valvulata D'ORB.

Rosalina valvulata D'ORB., 1826, Tab. Méth., An. Sc. Nat. VII. p. 271, No. 4.
? *D. valvulata* BR., 1884, Chall. Rep., IX. p. 644, Pl. LXXXVII. Figs. 5–7.
D. valvulata GOËS, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 106, Pl. VIII. Figs. 258–261.

Is not common on the east side of Isthmus on bottoms of moderate depths.
Caribbean Sea. 300 fathoms (Goës).

D. Berthelotiana D'ORB.

Rosalina Berthelotiana D'ORB., 1839, Iles Canaries, p. 135, Pl. I. Figs. 28–30.
D. Berthelotiana GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 107, Pl. VIII. Figs. 266–268.
D. Bertheloti BR., 1884, Chall. Rep., IX. p. 650, Pl. LXXXIX. Figs. 10–12.

Is not uncommon in moderate depths.
Caribbean Sea. 300 fathoms (Goës).

ROSALINA D'ORB.

R. Poëyi D'ORB.

Rosal. Poëyi D'ORB., 1839, For. Cuba, p. 92, Pl. III. Figs. 18–20.
Discorbina Poëyi GOËS, 1882, Ret. Rhiz. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 107, Pl. VIII. Figs. 264, 265.
Cymbalopora Poëyi BR., 1884, Chall. Rep., IX. p. 636, Pl. CII. Figs. 13, 14.

This form is not uncommon both in shallow and deeper water in the Caribbean Sea. This and the following form the authors usually, after Carpenter's sample, refer to Hagenow's *Cymbalopora*; but as Hagenow's original figure seems very little or not at all to represent a foraminiferal form, his name ought to be abandoned in the rhizopodology. Since d'Orbigny's genus *Rosalina* has been totally substituted by other names, it seems proper to re-establish the genus *Rosalina* for forms referred to *Cymbalopora*.

Caribbean Sea. 300 fathoms (Goës).

R. bulloides d'Orb.

Rosalina bulloides d'Orb., 1839, For. Cuba, p. 98, Pl. III. Figs. 2–5.
Tretomphalus bulloides Moebius, 1880, Meeresfauna Mauritius u. Seychell., p. 98, Pl. X. Figs. 6–9.
Discorbina bulloides Goës, 1882, Ret. Rhiz. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 106, Pl. VIII. Figs. 262, 263.

This singular form of a modified *Discorbina* is not uncommon in the Caribbean Sea.

Caribbean Sea. 300 fathoms (Goës).

PLANORBULINA d'Orb.

P. lobatula Walk. & Jac.

Nautilus lobatulus Walk. & Jac., 1798, Adams's Essay (ed. Kanmacher), p. 642, Pl. XIV. Fig. 36.
Truncatulina lobatula d'Orb., 1839, Iles Canaries, p. 134, Pl. II. 22–24.
T. lobatula Br., 1884, Chall. Rep., IX. p. 660, Pl. XCII. Fig. 10, Pl. XCIII. Figs. 1, 4, 5, Pl. XCV. Figs. 4, 5.
Planorbulina lobatula Goës, 1874, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 88, Pl. XV. Fig. 774.

Of this wide-spread form a few well developed specimens were found by the "Albatross" in the Caribbean Sea. They have all their characteristics in common with Northern congeners, but seem to affect deeper water than those which in their typical state usually belong to the littoral and shallow zone.

Caribbean Sea. 399–463 fathoms; scarce.

P. Wüllerstorfi Schwag.

Anomalina Wüllerstorfi Schwag., 1866, For. Kar Nikob., Novara Reise, Geol., Th. II. p. 258, Pl. VII. Figs. 105, 107.
Truncatulina wuellerstorfi, Br., 1884, Chall. Rep., IX. 9, p. 622, Pl. CXIII. Figs. 8, 9.
Planorbulina Wüllerstorfi Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 89, Pl. XV. Fig. 777.

Is an intermediate form between *lobatula* and *ariminensis*, and sometimes difficult to distinguish from the former ; it seems to take its highest development at about 1000 fathoms depth. Its segments are mostly narrow, but in less developed samples their breadth and number approximate to that of *lobatula*.

Pacific. 695–1201 fathoms. Not scarce.

Caribbean Sea. 789–1630 fathoms. Not scarce, but less developed.

P. Ungeriana D'ORB.

Rotalia Ungeriana D'ORB., 1846, For. Bass. tert. Vienne, p. 157, Pl. VIII. Figs. 16–18 (more flat).

Planorb. Ungeriana GOËS, 1882, Ret. Rhiz. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 100, Pl. VII. Figs. 234–236.

Truncatulina Ungeriana BR., 1884, Chall. Rep., IX. p. 664, Pl. XCIV. Fig. 9.

Planorbulina Ungeriana GOËS, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 90, Pl. XV. Fig. 780.

Planorbulina Ungeriana var. *affixa* GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., Ibid., p. 103, Pl. VII. Figs. 237–241.

Becomes in deep water of tropic seas more tumid and has the edge more rounded than the type represented by d'Orbigny, and also by Brady in his Shetland Rhizopodes, Trans. Lin. Soc. London, XXIV. Pl. XLVIII. Fig. 12. Usually it has a flat, often somewhat uneven or granulated boss on the centrum of the oral side, and also a small pellucid one on its aboral centrum ; but in starved specimens often one or the other is missing. Its principal features are the numerous segments of the last whorl (11–14), and the relative smallness of the pores.

The *Planorbulina* (*Rotalina*) *rosea* of d'Orbigny can scarcely be specifically distinguished from our West Indian form; it has a somewhat elevated trochoid spire and affects shallower water in the Caribbean Sea.

Planorb. Ungeriana has received a variety of names not only from different authors but also from one and the same author.

It is sometimes affixed and assumes then a flat outspread shape, somewhat like *lobatula*, with strongly lobated edge (var. *affixa* GOËS), Pl. VII. Figs. 1–3.

Caribbean Sea. 196–966 fathoms; not scarce.

ALLIED FORM:—

P. mundula BRADY, PARK. & JONES.

Truncatulina mundula BR., PARK. & JONES, 1888, For. Abrohlos Bank, Trans. Zoöl. Soc. Lond., XII. 7, p. 228, Pl. XLV. Fig. 25.

? BRADY, Chall. Rep., IX. Pl. XCV. Fig. 6.

Is not very distinct from *Ungeriana*, its main characteristics being its biconvex shape, with somewhat extenuated margin, the evoluted convolutions, the sutural limbation and plain poration of the aboral side; the number of segments in the outer whorl varying from 7 to 13. The oral

side is sometimes provided with an umbilical depression, but often without it; the poration on this side is usually obsolete, the sutures nearly straight, without limbation. It may be identical with *Rotalia truncana* Gümb., 1868, Nordalp. Eocän, K. Bayr. Wiss. Ak., Abh. X. p. 653, Pl. II. Fig. 93.

Pacific. 695–1218 fathoms; not common.

P. Robertsoniana Brady.

Truncatulina Robertsoniana Br. (1881), 1884, Chall. Rep., IX. p. 664, Pl. XCV. Fig. 4.

Is distinguished by its often wide umbilicus on the oral side, its nearly flat aboral side, and several narrow circumvolutions with numerous segments. Color usually brown or yellowish, seldom white.

Caribbean Sea. 399–1830 fathoms; not common.

P. reticulata Czjzek.

Rotalina reticulata Czjz., 1848, For. Wien. Beck., Haid. Nat., Abh. II. p. 145, Pl. XIII. Figs. 7–9.

Planorb. reticulata Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 103, Pl. VII. Figs. 242–244.

Truncat. reticulata, Br., 1884, Chall. Rep., IX. p. 669, Pl. XCVI. Figs. 5–8.

This exquisite form is of no rare occurrence in some localities of the Caribbean Sea.

Caribbean Sea. 300 fathoms (Goës).

P. Ariminensis d'Orb.

Planulina Ariminensis d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 280, Pl. V. Figs. 1–3, bis Mod. 49.

Planorb. tuberosa var. *Ariminensis* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 98, Pl. VII. Figs. 228–233.

Anomalina Arimininensis Br., 1884, Chall. Rep., IX. p. 674, Pl. XCIII. Figs. 10, 11.

Planorb. Arimininensis Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 91, Pl. XV. Figs. 784, 785.

A handsome form, that has been found in a well developed state in the Caribbean Sea.

Caribbean Sea. 196–684 fathoms.

P. rudis Gümbel.

Rosalina rudis Gümb., 1868, Nordalp. Eocän, K. Bayr. Wiss. Ak., Abh. X. p. 657, Pl. II. Fig. 99.

Anomalina grosserugosa Br., 1884, Chall. Rep., IX. p. 673, Pl. XCIV. Figs. 4, 5.

It may be questioned whether the form represented by Brady in the Challenger Report as *Anomal. grosserugosa* is quite identical with Gümbel's form of the same name, which seems to be rather a *Truncatulina* than an *Anomalina*,

which latter is represented by Brady. But Gümbel has described and designed another form that seems to be much nearer Brady's *grosserugosa*, i. e. *Rosalina rudis*. It is, like our form, 6-segmented in the outer convolution, provided with rounded edge, and is nearly spironautiloid like ours. Sometimes both sides are so nearly involute that the test becomes nearly nautiloid.

Pacific. 770–1201 fathoms; scarce.

Caribbean Sea. 210 fathoms; very rare.

P. ammonoides Reuss.

Rotalina Lamarckiana d'Orb., Iles Canaries, p. 131, Pl. II. Figs. 13–15, is a pygmy form, that differs only in having the oral side nearly involute.

Rosalina ammonoides Reuss, 1846, Böhm., Kreidef., I. p. 36, Pl. VIII. Fig. 53, Pl. XIII. Fig. 66.

Rosalina ammonoides Reuss, Kreidemergel Lemberg, Haid. Naturwiss., Abh. IV. p. 36, Pl. III. Fig. 2.

Truncatulina ammonoides Br., 1884, Chall. Rep., IX. p. 672, Pl. XCIV. Figs. 2, 3.

Differs from the preceding in scarcely anything but the greater number of segments (10–13). The form of Reuss from the Bohemian and Galician chalk differs slightly from our recent one in having the oral side also nearly involute.

Caribbean Sea. 210–382 fathoms; very scarce.

P. farcta Ficht. & Moll.

Nautilus farctus Ficht. & Moll., 1803, Test. Micr., p. 64, Pl. IX. Figs. *g–i*.

Planorbulina farcta Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 95, Pl. VII. Figs. 220–225.

Belongs to the more loosely built Planorbulinæ, with large poration and somewhat rough surface. The figure of Ficht. & Moll. is wanting a view of the spire side, and besides not satisfactory. It has generally 6–7 segments in its last convolution. Its arrangement of its anfractus is sometimes quite Rotaliniform, but sometimes nearly nautiloid, the spire being hidden by the succeeding anfractus. Its usual size is from 0.50 to 0.60 mm.

Caribbean Sea. 300 fathoms; not scarce (Goës).

P. mediterranensis d'Orb.

P. mediterranensis d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 280, Pl. XIV. Figs. 4–6, Mod. 79.

P. farcta var. *vulgaris* Goës, Ret. Rhiz. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 97, Pl. VII. Fig. 227; Fig. 226, *P. acervalis* Br.

P. mediterranensis Br., 1884, Chall. Rep., IX. p. 656, Pl. XCII. Figs. 1–3; Fig. 4, *P. acervalis* Br.

P. mediterranensis Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 91, Pl. XV. Fig. 786.

A pygmy form of this species is not seldom met with in the Caribbean Sea in 300 fathoms water. A variety of higher development that Brady has described under a separate denomination (*P. acervalis*) is also joined with the type, but of more rare occurrence.

Caribbean Sea. 300 fathoms (Goës).

CARPENTERIA Gray.

C. proteiformis Goës.

Plate VI. Figs. 8-17.

C. balaniformis Gray var. *proteiformis* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 94, Pl. VI. Figs. 208–214, Pl. VII. Figs. 215–219.
C. proteiformis Br., 1884, Chall. Rep., IX. 9, p. 679, Pl. XCVII. Figs. 8–14.

A form that can scarcely be defined with ordinary characteristics, so great are its variations of form, as shown on our Plate.

Caribbean Sea. 400 fathoms; in certain places not scarce (Goës).

RUPERTIA Wallich.

R. stabilis Wall.

R. stabilis Wallich, 1877, a new sessile Foraminifer from N. Atlantic, An. Mag. Nat. Hist. (4.), XIX. p. 501, Pl. XX. Figs. 1–4.
R. stabilis Br., 1884, Chall. Rep., IX. p 680, Pl. XCVIII. Figs. 1–12.
R. stabilis Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 92, Pl. XV. Fig. 789.

A few specimens of this remarkable Foraminifer, most of them in a half-grown state, have been met with in the Pacific, usually attached to arms of Rhabdammina. The last convolution is wider than usual in Northern specimens.

Pacific, off Acapulco. 772 fathoms.

GYPSINA Carter.

G. vesicularis var. discus Goës.

Plate VII. Figs 4–6.

Tinoporus vesicularis Goës, 1882, Ret. Rhiz. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 104, Pl. VII. Figs. 245–247.

A variety closely allied to the type, from which it differs only in its lenticular shape, and its more plainly differentiated set of the central cycle of chambers. It is not found affixed.

Caribbean Sea. 400 fathoms; scarce (Goës).

POLYTREMA Milne-Edw.

P. miniaceum Lin.

Millepora miniacea Lin., 1788, Syst. Nat., ed. 13, p. 3784.
Polytrema miniaceum Br., 1884, Chall. Rep., IX. p. 721, Pl. C. Figs. 5–9, Pl. CI. Fig. 1.

As inhabitant of shallow water, this form is sparsely represented in the "Albatross" dredgings.

Caribbean Sea. 115 fathoms.

PULVINULINA Park. & Jones.

P. repanda Ficht. & Moll.

Nautilus repandus Ficht. & Moll., 1803, Tert. Micr., p. 35, Pl. III. Figs. *a–d*.
P. repanda Park. & Jones, 1862, Carpenter's Introduction, p. 210.
P. repanda Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 110, Pl. VIII. Figs. 276–282.
P. repanda Br., 1884, Chall. Rep., IX. p. 684, Pl. CIV. Fig. 18.
P. repanda Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 95, Pl. XVI. Fig. 801.

Is very imperfectly represented in dredgings of the "Albatross," although in moderate depths of the Caribbean Sea it is not very rare.

Caribbean Sea. 100–400 fathoms (Goës).

Allied Form:—

P. exigua Brady.

P. exigua Br., 1884, Chall. Rep., IX. p. 696, Pl. 103, Figs. 13, 14.

A pygmy form, with 5–6 segments only in the outer convolution.
Pacific. 1218 fathoms; rare.

P. Menardii d'Orb.

Rotalia Menardii d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 273, No. 26, Mod. 10.
P. Menardii Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 112, Pl. VIII. Figs. 289–295.
P. Menardii Br., 1884, Chall. Rep., IX. p. 690, Pl. CIII. Figs. 1, 2, var. Figs. 3–6.

This pelagic species occurs in all Globigerina ooze of both oceans.
On both sides of Isthmus. Pelagic.

P. Micheliniana d'Orb.

Rotalia Micheliniana d'Orb., 1840, For. Craie bl. Paris, Mém. Soc. Géol. France, IV. p. 31, Pl. III. Figs. 1–3.
P. Micheliniana Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 114, Pl. VIII. Figs. 296–298.
P. Micheliniana Br., 1884, Chall. Rep., IX. p. 694, Pl. CIV. Figs. 1, 2.

Also a pelagic species, that nearly always accompanies the preceding in both oceans. Although the form represented by d'Orbigny in his memoir on the Chalk Foraminifera from Paris does not quite agree with our recent form, its margin not tending to an angulous circumference, as in the latter form; but that feature is of too small importance to establish a specific denomination for our form.

On both sides of Isthmus. Pelagic.

ALLIED FORM:—

P. crassa d'ORB.

Rotalina crassa d'ORB., 1840, For. Craie bl. Paris, Mém. Soc. Géol. France, IV. p. 32, Pl. III. Figs. 7, 8.
P. crassa BR., 1884, Chall. Rep., IX. p. 694, Pl. CIII. Figs. 11, 12.

Although Brady's designation of d'Orbigny's form from the Chalk of Paris does not exactly agree with this, it is not necessary to adopt a new name for the recent variety, the discrepancies being too trifling between the two forms. The recent one has usually the last circumvolution divided into four segments, while d'Orbigny's form has six; the aperture is also wider in the latter.

Caribbean Sea. A single specimen only found; probably pelagic.

P. elegans d'ORB.

Rotalia (*Turbinulina*) *elegans* d'ORB., Tab. Méth., An. Sc. Nat., VII. p. 276, No. 54.
Rotalina Partschiana d'ORB., 1846, Bass. tert. Vienne, p. 153, Pl. VII. Figs. 28–30, Pl. VIII. Figs. 1–3.
P. elegans GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 111, Pl. VIII. Figs. 283–285.
P. elegans, partschiana BR., 1884, Chall. Rep., IX. p. 699, Pl. CV. Figs. 3–6.
P. elegans GOËS, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 97, Pl. XVI. Fig. 808.

Reaches a high development in deep water, particularly in the Pacific. The large specimens have the sutures less limbated, the edge sharper, and the spiral side more flat, than the smaller ones. The aperture is usually a narrow slit on the marginal top of the last segment, but sometimes it has the regular situation in common with its congeners, being very narrow. Sometimes such an aperture continues in an apical slit.

Pacific. 695–1832 fathoms; not scarce.

Caribbean Sea. 300–1830 fathoms; smaller, and not so common.

P. Schreibersii d'ORB.

Rotalina Schreibersii d'ORB., 1846, Bass. tert. Vienne, p. 154, Pl. VIII. Figs. 4–6.
P. elegans var. *trochus* GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 112, Pl. VIII. Figs. 286–288.
P. schreibersii BR., 1884, Chall. Rep., IX. p. 697, Pl. CXV. Fig. 1.

Is not of rare occurrence in the Caribbean Sea; the circumvolutions and sutures on the spiral side are often hidden by a cupula of exogenous polished white shell substances.

Caribbean Sea. 200 fathoms (Goës).

P. pauperata Park. & Jones.

P. repanda var. *pauperata* Park. & Jones, 1865, Arct. & North Atl. Oceans, Philos. Trans., CLV. p. 395, Pl. XVI. Figs. 50, 51.
P. pauperata Br., 1884, Chall. Rep., IX. p. 696, Pl. CIV. Figs. 3–11

This broad-winged singular form is a prominent constituent of the abyssal Foraminifera ground on both sides of the Isthmus. It seems to arrive at a higher development in the Pacific.

Pacific. 770–1132; plenty.

Caribbean Sea. 347–1920 fathoms; not scarce.

P. auricula Ficht. & Moll.

Nautilus auricula Ficht. & Moll., 1803, Test. Micr., p. 108, Pl. XX. Figs. *a–c*.
P. auricula Br., 1884, Chall. Rep., IX. p. 688, Pl. CVI. Fig. 5.
P. auricula Goës, 1882, Sv. Vet. Ak. Hdl., XIX. 4, p. 109, Pl. VIII. Figs. 273–275.
P. auricula Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 98, Pl. XVI. Figs. 809, 810.

Not common in the tropical seas. It cannot be specifically distinguished from *Rotal. oblonga* Williams. The broad form represented in Chall. Rep., Pl. CVI., under the name of *P. oblonga*, does not quite agree with Williamson's form.

Caribbean Sea. 169 fathoms; scarce.

P. Hauerii d'Orb. var. semiplecta Schwag.

Rotal. Hauerii d'Orb., 1846, Bass. tert. Vienne, p. 151, Pl. VII. Figs. 22–24.
P. hauerii Br., 1884, Chall. Rep., IX. p. 690, Pl. CVI. Figs. 6, 7.
P. subinflata, semiplecta, Mölleri, Schwag., 1883, For. Eocän, Libysche Wüste, Palæontogr., XXX. 1, pp. 52, 53, Pl. IV. Figs. 15, 16, Pl. V. Fig. 6.

Differs from the type of d'Orbigny in its less rounded margin and more inequilateral shape, the margin being at nearly equal level with the spiral side. Our form has from 7 to 9 segments in the outer convolution. It is usually broader than the type.

Schwager has described two other forms, *P. subinflata* and *P. Mölleri*, with no specific characters that distinguish them from *semiplecta*.

Rot. Brongniartii d'Orb., Bass. tert. Vienne, p. 158, Pl. VIII. Figs. 22–24, can hardly be distinguished but by its thinner edge from *P. Hauerii*, and may be considered as a broader *auricula*. Our present form comes near Brady's *oblonga*, Chall. Rep., IX. Pl. CVI. Fig. 4, both in the number of segments and in the limbation of the sutures, but our form is broader, approaching to orbicular *Rotalinæ*.

Pacific. 1201 fathoms. Scarce.

ROTALINA (Lmck.) d'Orb.

R. Soldanii d'Orb.

Gyroidina Soldanii d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 278, No. 5, Mod. 36.
G. orbicularis d'Orb., Ibid., p. 278, No. 1, Mod. 13.
R. Soldanii d'Orb., 1846, Bass. tert. Vienne, p. 155, Pl. VIII. Figs. 10–12.
R. Soldanii Br., 1884, Chall. Rep., IX. p. 706, Pl. CVII. Figs. 6, 7.
R. Soldanii Goës, 1894, Sv. Vet. Ak. Hdl., XXV. 9, p. 99, Pl. XVI. Fig. 812.

Differs not essentially from *Rot.* (*Gyroidina*) *orbicularis* d'Orb., Mod. 13. This seems only to be of a weaker growth, provided with six to eight segments only in the outer convolution, while *R. Soldanii* usually has nine. The small convexity on the spiral side is in both nearly alike. In Chall. Rep., Brady has figured both forms, but his figures offer no characteristics for a differentiation.

Pacific. 1200 fathoms; rare.

Caribbean Sea. 347–1051 fathoms; scarce.

POLYSTOMELLA d'Orb..

P. striatopunctata Ficht. & Moll.

?*Nautilus striatopunctatus* Ficht. & Moll., 1803, Test. Microsc., p. 61, Pl. IX. Figs. *a–c*.
Polystomella Poëyana d'Orb., 1839, For. Cuba, p. 55, Pl. VI. Figs. 25, 26.
P. crispa var. *Poëyana* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 116, Pl. VIII. Figs. 301, 302.
P. striatopunctata Br., 1884, Chall. Rep., IX. p. 733, Pl. CIX. Figs. 22, 23.

Occurs rarely in a somewhat modified form in the Caribbean Sea.

Caribbean Sea. 300 fathoms (Goës).

NONIONINA d'Orb.

N. umbilicatula Montagu.

Nautilus umbilicatulus Montagu, 1803, Test. Brit., Supplem., p. 78, Pl. XVIII. Fig. 1.
Non. umbilicatula Br., 1884, Chall. Rep., IX. p. 726, Pl. CIX. Figs. 8, 9.
Non. umbilicatula Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 103, Pl. XVII. Figs. 823, 824.

Is represented in "Albatross" dredgings by two specimens only.

Pacific. 995–1201 fathoms; very scarce.

N. depressula Walk. & Jac.

Naut. depressulus Walk. & Jac., 1798, Adams's Essays Microsc. (Kanmach ed.), p. 641, Pl. XIV. Fig. 33.
Discorb. vesicularis var. *elegans*, Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 108, Pl. VIII. Figs. 269–271.
Non. depressula Br., 1884, Chall. Rep., IX. p. 725, Pl. CIX. Figs. 6, 7.

Is seldom met with in the Caribbean Sea, and always in a starved condition; it has a tendency to the *stelligera* form of d'Orbigny.

Caribbean Sea. 300 fathoms (Goës).

N. scapha Ficht. & Moll.

Nautilus scapha F. & M., 1803, Test. Micr., p. 105, Pl. XIX. Figs. *d–f.*
Polystomella crassula var. *scapha* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 114, Pl. VIII. Figs. 299, 300.
Non. scapha Br., 1884, Chall. Rep., IX. p. 730, Pl. CIX. Figs. 14–16.
Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 104, Pl. XVII. Fig. 830.

Occurs scantily and in a somewhat starved condition in the Caribbean Sea. It is usually extremely compressed, while the Northern form is much inflated.
Caribbean Sea. 300 fathoms (Goës).

AMPHISTEGINA d'Orb.

A. vulgaris d'Orb.

A. vulgaris, Lessonii, etc., d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 305, No. 8, p. 304, No. 3, Mod. 98, Pl. XVII. 1–4.
A. lessonii Br., 1884, Chall. Rep., IX. p. 740, Pl. CXI. Figs. 1–7.

Is one of the commonest forms in shallow water and moderate depths in the Caribbean Sea. Out of the many names it at first received by d'Orbigny the above seems to me the most suitable.
Caribbean Sea. 30–300 fathoms; common.

HETEROSTEGINA d'Orb.

H. depressa d'Orb.

H. depressa d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 305, No. 2, Mod. 99, Pl. XVII. Figs. 5–7.
H. depressa Br., 1884, Chall. Rep., IX. p. 746, Pl. CXII. Figs. 14-20.
H. simplex d'Orb., 1846, Bass. tert. Vienne, p. 211, Pl. XII. Figs. 12–14.
H. depressa var. *simplex* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 117, Pl. VIII. Fig. 303.

Is often found with *Amphistegina Lessonii* d'Orb., but of far rarer occurrence. Its variety with less divided chambers, *Het. simplex* d'Orb., is also met with in the Caribbean Sea.
Caribbean Sea. 300 fathoms; rare (Goës).

CORNUSPIRA Schultze.

C. foliacea Phil.

Orbis foliaceus Phil., 1844, Mol. Sicil., II. p. 147, Pl. XXIV. Fig. 26.
Cornuspira planorbis Schultze, 1854, Organ. Polythal., p. 40, Pl. II. Fig. 21.
C. foliacea Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 120, Pl. IX. Fig. 308.

C. foliacea Br., 1884, Chall. Rep., IX. p. 199, Pl. XI. Figs. 5–9.
C. foliacea Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 106, Pl. XVIII. Fig. 834.

Is often met with both in moderate depths and in very deep water on both sides of the Isthmus.

Pacific. 700–1201 fathoms.
Caribbean Sea. 20–300 fathoms; not scarce.

SPIROLOCULINA d'Orb.

S. canaliculata d'Orb.

S. canaliculata d'Orb., 1846, Bass. tert. Vienne, p. 269, Pl. XVI. Figs. 10–12 (young and compressed).

This variety can but faintly be distinguished either from the typic *planulata* Lamarck, or from *limbata* both of d'Orbigny and Bornem. In full grown specimens the margin is very dilated, and often its furrow is shallow, nearly obsolete. The contour varies from pointed elliptical to nearly round. The scooped out sides of the segments make the sutures rise to a sort of limbation. Length, 1 mm.

Caribbean Sea. 300 fathoms (Goës).

S. asperula Karr.

S. asperula Karr., 1868, Mioc. Foramf. Kostej., Wien. Ak. Sitz. Ber., LVIII. p. 137, Pl. I. Fig. 10.
S. asperula Br., 1884, Chall. Rep., IX. p. 152, Pl. VIII. Figs. 13, 14.

Very indistinctly and scantily represented in the "Albatross" collections.

Pacific. 1132 fathoms; rare.

S. robusta Brady.

S. robusta Br., 1884, Chall. Rep., IX. p. 150, Pl. IX. Figs. 7, 8.

This prominent species is represented in a few well developed samples from the "Albatross" collections. Full grown specimens have often the last segments obtusely carinate, the keel often dividing itself into the 3 or 4 weak ribs.

Caribbean Sea. 210 fathoms; rare.

SIGMOILINA Schlumberger.

S. sigmoidea Brady.

Planispirina sigmoidea Br., 1884, Chall. Rep., IX. p. 197, Pl. II. Figs. 1–3; woodcut, p. 194.
Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. IX. Figs. 330–334.
S. sigmoidea Schlumb., 1887, Genre Planispirina, Bull. Soc. Zool. Fr., XII. p. 106, Pl. VII. Figs. 9–11.

This species varies in the marginal contour from elliptic to nearly circular. The white gloss of the surface and the shape of the aperture suggest proximity to some forms of *Biloculina*.

Caribbean Sea. 300–1069 fathoms; rare.

S. celata Costa.

Spiroloc. celata Costa, 1854, Palæont. Napoli, Pl. XXVI. Fig. 5.
Spiroloc. celata Costa, 1855, For. Vaticano, Mem. Napol., II. p. 126, Pl. I. Fig. 14.
Quinqueloc. asperula Seg., 1862, Rhizop. Catania, Accad. Gioenia Atti (2.), XVIII. p. 118, Pl. II. Fig. 6.
Planispirina celata Br., 1884, Chall. Rep., IX. p. 197, Pl. VIII. Figs. 1–4.
Sigmoilina celata Schlumb., 1887, Genre Planispir., Bull. Soc. Zool. Fr., XII. p. 111, Pl. VII. Figs. 12–14.
? *Quinqueloc. rugosa* Schwag., 1866, For. Kar Nikob., Novara Reise, Geol., Th. II. p. 203, Pl. IV. Fig. 16.

The figure of *Spiroloculina celata* given by Costa in the Palæontology of Napoli is not quite satisfactory for a reliable identification; but as it on the whole in its outlines agrees with Brady's designs in Chall. Rep., this author may be justified in identifying his form with that of Costa.

The genus *Sigmoilina* of Schlumberger has been founded on the regular semispiral arrangement of the segments; but such a disposition of the chambers will be observed to take place in most species of *Quinqueloculina*, the chief difference being usually the greater number of segments in each semi-spiral; but even that characteristic does not hold good in the newly founded genus.

Caribbean Sea. 200–1000 fathoms; not common.

MILIOLINA (Lmck.) Park. & Jones.

M. seminulum Lin.

This species becomes in deep water usually broader and with more sharp margin than in the shallow-water form. Such broad forms have been recorded under different names, as *Quinqueloc. triangularis* d'Orb. (Bass. tert. Vienne, p. 288, Pl. XVIII. Figs. 7–9); also represented by Parker and Jones, and Brady's Crag Foramf., Palæont. Soc., XIX. Pl. IV. Fig. 1, Pl. VI. Fig. 2, and by Bornemann under the name of *Quinqueloc. Ermanni* (Septar. Thon Hermsdorf, Zeitschr. deutsch. geol. Gesellsch., VII. p. 351, Pl. XIX. Fig. 6), and so on. When the margin becomes very sharp keeled, it has been subject to new names, as *Quinqueloc. Buchiana*, *Ungeriana*, *Partschii*, *longirostra* d'Orb. (Bass. tert. Vienne), and *Lamarckiana*, *Cuvieriana*, *Auberiana* d'Orb. (For. Cuba).

In Chall. Rep. (Pl. V. Figs. 8, 9) Brady has conferred the name *Miliolina Auberiana* upon a broad *triangularis* with sharp margins, but which in other respects does not exactly agree with d'Orbigny's figure.

Such forms are found together with *triangularis*, intermediate forms being

always met with which are not provided with keels on the two segments preceding the two last ones.

Caribbean Sea. 300–800 fathoms; not plenty.

ALLIED FORMS:—

1. **M. procera** GOËS. Plate VII. Figs. 7–9.

This is a short inflated variety of *seminulum*. The aperture is usually an undulating irregular slit, like that in certain forms of *Biloculina*. Sometimes a faint longitudinal striation on the antepenultima segment is discoverable. It seems to be closely allied to *M. circularis* (BORNEM.) BR., the chief difference being its quinqueloculine arrangement of the chambers. Besides, it may be identical with the inflated forms exhibited by Bornemann as *Quinqueloc. ovalis* and *cognata* from Septaria clay, and *impressa* and *regularis* REUSS, all forms which can hardly be distinguished from *circularis* except by their quinqueloculine structure. Length 2.40 mm.

Pacific. 885 fathoms; scarce.

Caribbean Sea. 885 fathoms; not common.

2. **M. circularis** BORNEM.

Triloculina circularis BORNEM., 1855, Sept. Thon Hermsdorf, Zeitschr. deut. geol. Gesellsch., VII. p. 349, Pl. XIX. Fig. 4.

Mil. circularis BR., 1884, Chall. Rep., IX. p. 169, Pl. IV. Fig. 3.

An ill defined form, with usually inflated segments in a triloculine arrangement, and a crescentic or somewhat angular mouth. It has often a longitudinal impression on both sides of the antepenultima segment, but this feature is not at all constant.

Pacific. 885 fathoms; scarce.

Caribbean Sea. 978 fathoms; scarce.

3. **M. contorta** D'ORB., var. Plate VII. Figs. 10–12; Plate VIII. Figs. 1–7.

Quinqueloc. contorta D'ORB., 1846, Bass. tert. Vienne, p. 298, Pl. XX. Figs. 4–6.

? *Quinqueloc. annectens, rugosa* SCHLUMB., 1893, Mém. Soc. Zool Fr., VI. Pl. III. Figs. 77–79, Pl. IV. Figs. 91–93.

Mil. contorta GOËS, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 111, Pl. XX. Figs. 851, 852.

In his memoir on Fossil Foraminiferæ of the tertiarian basin at Vienna, d'Orbigny has described and designed a set of *Quinqueloculinæ* characterized principally by their truncate or hollowed margin of the two last segments and the more or less angular projection of the two or three preceding ones. The most of those forms are too closely allied to be ranked as species, and the small differences are too fickle to entitle them even to varietal denomination.

With more or less reason some authors have reunited some of these forms under d'Orbigny's *Quinqueloc. Ferusacii*, seemingly a thinner form, but with the same leading features as the Vienna forms. In the mean time

I have chosen *M. contorta* D'ORB., as joining the most of the features of recent forms belonging to this set, as the typical form. Sometimes the margin of one of the outer segments, usually that of the penultimate, is sharp and thin, without furrow (*Quinqueloc. Mariæ* D'ORB.). And when also the corresponding opposite segment is bordered by a thin margin, provided with a narrow channel, such forms approximate very nearly to the carinated *Lamarckiana* D'ORB. and its allies.

Stout specimens have sometimes the marginal furrow of the last segment divided by a middle rib, as in *Quinqueloc. Rodolphina* D'ORB. It is not seldom provided with a short neck. In the temperate seas it is usually somewhat agglutinated of fine sand.

From *Quinqueloc. concava* REUSS (Pl. VII. Figs. 8–10) and *excavata* KARRER it can scarcely be specifically distinguished, those forms usually being thinner.

Caribbean Sea. 159 fathoms; scarce.

4. **M. polygona** D'ORB. Plate VIII. Figs. 11–18.

Quinqueloc. polygona D'ORB., 1839, For. Cuba, p. 198, Pl. XII. Figs. 21–23.
Mil. polygona GOËS, 1894, Sv. Vet. Ak. Hdl., XXV. 9, p. 111, Pl. XX. Figs. 854–854 *g*; GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. IX. Figs. 353, 354.

Differs little from the preceding variety, the chief difference being the truncation even of the antepenultima segment. The surface of this variety is also unpolished. The antepenultima segment is sometimes faintly striated.

Caribbean Sea. 300–400 fathoms; rare (Goës).

5. **M. bicostata** D'ORB. Plate VIII. Figs. 19–21.

Quinqueloc. bicostata, D'ORB., 1839, For. Cuba, p. 195, Pl. XII. Figs. 8–10.
Mil. seminulum var. GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. IX. Figs. 351, 352.
Mil. bicostata GOËS, 1894, Sv. Vet. Ak. Hdl., XXV. 9, p. 112, Figs. 855 *a*, *b*.

Distinguished by the margin of the last two segments being broadly bitricarinated, and the other segments also usually provided with a relatively high keel or rib. D'Orbigny's figures probably represent a very young specimen.

Caribbean Sea. 300–400 fathoms (Goës).

M. tricarinata D'ORB.

Triloculina tricarinata D'ORB., 1826, Tab. Méth., An. Sc. Nat., VII. p. 299, No. 7, Mod. 94.
Mil. tricarinata GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. IX. Figs. 337–340, 355.
Mil. tricarinata BR., 1884, Chall. Rep., IX. p. 165, Pl. III. Fig. 17.
Mil. tricarinata GOËS, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 114, Pl. XXI. Figs. 866–869.

Has usually an oblong shape, but instances are not rare also of a nearly equilateral form. The few samples exhibited in the "Albatross" collection are very small and extenuated.

Pacific. 1218 fathoms; scarce.

Caribbean Sea. 300 fathoms (Goës).

M. consobrina d'Orb.

Triloculina consobrina d'Orb., 1846, Bass. tert. Vienne, p. 277, Pl. XVII. Figs. 10–12.
Triloculina angustissima, nitens, pygmæa, Reuss, 1849, Neue For. Oesterr., Wien. Ak. Dkschr., I. pp. 383–385, Pl. XLIX. Figs. 10, 18, Pl. L. Fig. 3.
Triloculina nitida d'Orb., 1874, For. Iles Canaries, p. 141, Pl. III. Figs. 22–24.
? *Quinqueloc. Bosciana* d'Orb., 1839, For. Cuba, p. 191, Pl. XI. Figs. 22–24.
Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. IX. Fig. 328.

In three of his works on Foraminifera d'Orbigny has given figures and descriptions of a set of *Triloculinæ* closely allied to *Vermiculum oblongum* of Montagu, not well distinguished either from the latter or from each other. *M. consobrina* of d'Orbigny represents a form of more linear and narrower shape than the common *oblonga*, which is more oval in circumference. The antepenultima segment is usually not projecting but flush in the former.

Our form from the Caribbean Sea is very slender and with nearly equal linear contour, very slightly compressed, thin-shelled, and with an aperture very much like that of the *consobrina* of d'Orbigny.

Length 0.80 mm.; breadth 0.20 mm.

Caribbean Sea. Only one sample occurs in the "Albatross" collection; depth unknown.

BILOCULINA d'Orb.

B. sphæra d'Orb.

B. sphæra d'Orb., 1839, Voy. Amér. Mérid., V. p. 66, Pl. VIII. Figs. 13–16.
B. globulus Bornem., 1855, Sept. Thon Hermsdorf, Ztschr. deut. geol. Gesellsch., VII. p. 349, Pl. XIX. Fig. 3.
B. globulus Reuss, 1870; Schlicht, Septar. Thon Pietzpuhl, Pl. XXXV. Figs. 30–32 (not Reuss, Septarienth. Offenbach, Wien. Ak. Sitz. Ber., XLVIII. p. 40, Pl. I. Fig. 4, which is scarcely distinguishable from *B. bulloides* d'Orb., or from *B. abyssorum* Goës).
Miliol. ringens var. Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. X. Figs. 368, 369.
B. sphæra Br., 1884, Chall. Rep., IX. p. 141, Pl. II. Fig. 4.
B. sphæroides Schlumb., 1880, Feuille Jeunes Natur. (Separ), XIII. p. 22, Pl. II. Fig. 3.
Planispirina sphæra Schlumb., 1891, Biloc. grands fonds, Mém. Soc. Zool. France, IV. p. 190, Figs. 45, 46.
B. sphæra Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 120, Pl. XXV. Fig. 927.

Exhibits an aperture usually of two forms; the commonest is that of a transverse somewhat bended slit, the other is that of a V-formed fissure; some-

times the aperture is represented by one or two undulated irregular slits. The extent of the last segment's prevalence over the penultima one is also subject to some variableness. As a rule the surface is provided with a high gloss, but old and stout samples are often without this lustre.

Caribbean Sea. 300–1500 fathoms.

Pacific. 700–1300 fathoms; not common.

ALLIED FORM:—

B. irregularis D'ORB.

B. irregularis D'ORB., 1839, Voy. Amér. Mérid., p. 67, Pl. VIII. Figs. 20, 21.
B. irregularis BR., 1884, Chall. Rep., IX. p. 140, Pl I. Figs. 17, 18.
B. ventricosa REUSS, 1867, Steinsabz. Wieliczka, Wien. Ak. Sitz. Ber., LV. p. 69, Pl. I. Fig. 9.
B. grinzingensis KARRER, 1877, Hochquellen Wasserleit, K. K. geol. Reichsanst. Oesterr., IX. p. 375, Pl. XVI. Fig. 8.

An ovoid and marginally somewhat compressed form of *B. sphæra*, the apertural end being a little tapering and provided with a short semicircular aperture. It is sometimes triloculine, and then often more flattened from the margin.

Pacific. 885 fathoms; scarce.

Caribbean Sea. 382 fathoms; scarce.

B. bulloides var. **simplex** D'ORB.

B. simplex D'ORB., 1846, Bass. tert. Vienne, p 264, Pl. XV. Figs. 25–27.
Miliol. ringens GOËS, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 131, Pl. X. Figs. 361, 362.
B. ringens BR., 1884, Chall. Rep., IX. p. 142, Pl. II. Figs. 7, 8.
B. simplex GOËS, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 116, Pl. XXII. Figs. 872–882, Pl. XXIII. Figs. 886, 887.

Has been referred to *B. ringens* by several authors. But since Schlumberger has shown that the recent form differs slightly from the fossil form of Lamarck, there may be some reason to assign this variety to one of the many identical forms recorded by d'Orbigny, Reuss, etc.; for instance, *B. simplex* of d'Orbigny, somewhat distinct by its crescentic elongated aperture, usually of a long fibula form.

Caribbean Sea. 200–1500 fathoms; not rare.

ALLIED FORM:—

B. abyssorum GOËS. Plate IX. Figs. 1, 2.

B. abyssorum GOËS, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 118, Pl. XXIII. Figs. 888, 889.

A nearly globular or transversely ovoid form of *B. simplex*, often without prominent margin; its height (vertical diameter) often a little surpasses both the length and breadth. The aperture is often an angular bent or kneed narrow slit, sometimes much produced in length and irregularly kneed.

It may perhaps be identical with *Bil. globulus* Reuss, from Sept. Thon of Offenbach. Its shape reminds us also of *Bil. globulus* of Schlumberg, Revis. Biloc. grands fonds, Mém. Soc. Zool. France, IV. p. 188, Pl. XII. Figs. 97–100.

Some of the *enoplostoma* forms represented by Schlicht, Septar. Thon Pietzpuhl, Pl. XXXVI., seem also to belong to this variety.

Smaller specimens have often a glossy surface, like *sphæra*.

Caribbean Sea. 683 fathoms; scarce.

B. comata Brady.

Mil. ringens var. Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. X. Figs. 370, 371.

B. comata Br., 1884, Chall. Rep., IX. p. 144, Pl. III. Fig. 9.

B. comata Schlumb., 1891, Biloc. gr. fonds, Mém. Soc. Zool. Fr., IV. p. 178, Pl. X. Figs. 72, 73.

B. comata Goës, 1894, Arct. & Scand. For., Sv. Vet. Ak. Hdl., XXV. 9, p. 117, Pl. XXII. Figs. 383, 384.

Aperture usually short ◡ formed, the surface lines sometimes nearly obliterate; our form is pretty stout.

Caribbean Sea. 600–1500 fathoms; not common.

Allied Form: —

Mil. insignis Brady.

Mil. insignis Br. (1881), 1884, Chall. Rep., IX. p. 165, Pl. IV. Figs. 8–10.

Mil. ringens var. Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. X. Figs. 384, 385.

May be a triloculine form of *M. comata* Br., the habitus, the aperture, and the striation being the same in both.

Our specimens are of a stout, globular shape.

Caribbean Sea. 196–940 fathoms; scarce.

B. tubulosa Costa.

B. tubulosa Costa, 1854, Pal. Napoli, II. Pl. XXIV. Fig. 7.

B. lucernula Schwag., 1866, For. Kar Nikobar, Novara Reise, Geol., Th. II. p. 202, Pl. IV. Figs. 14, 17.

B. ringens var. *tubulosa* Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. X. Figs. 363–365, 376–383.

B. bulloides Br., 1884, Chall. Rep., IX. p. 142, Pl. II. Figs. 5, 6.

B. tubulosa, trigonula (partly) Br., Ibid., p. 147, Pl. III. Figs. 6, 14.

B. lucernula Schlumb., 1891, Biloc. gr. fonds, Mém. Soc. Zool. Fr., IV. p. 185, Pl. XII. Figs. 90–96.

B. tubulosa Goës, 1894, Sv. Vet. Ak. Hdl., XXV. 9, p. 118.

A more differentiated form, with coarser, often somewhat finely agglutinating surface and usually circular aperture on a short neck; its tri- or multiloculine larval stage structure has a propensity to continue through the adult stage.

Pacific. 772 fathoms.

Caribbean Sea. 1180 fathoms.

B. depressa d'Orb.

B. depressa d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 298, No. 7, Mod. 91.
B. depressa Br., 1884, Chall. Rep., IX. p. 145, Pl. II. Figs. 12, 15–17; Pl. III. Figs. 1, 2.
B. depressa Schlumb., 1891, Biloc. gr. fonds, Mêm. Soc. Zool. Fr., IV. Pl. IX. Figs. 48, 49.
B. depressa Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 120, Pl. XXV. Figs. 921–925.

This world-wide spread form attains in the depths of both oceans a high development. In the Pacific it assumes often a flat and expanded form with sharp edge, like *Bil. scutella* Karr.

Pacific. 700–1200 fathoms.
Gulf of Mexico. 200–1500 fathoms.

Allied Forms:—

1. **B. murrhina** Schwag.

B. murrhina Schwag., 1866, For. Kar Nikobar, Novara Reise, Geol., Th. II. p. 203, Pl. IV. Fig. 15.
B. depressa var. *murrhyna* Br., 1884, Chall. Rep., IX. p. 146, Pl. II. Figs. 10, 11.
B. murrhyna Schlumb., 1891, Biloc. gr. fonds, Mém. Soc. Zool. Fr., IV. p. 165, Pl. IX. Figs. 52–54.
B. depressa Park. & Jones, 1865, N. Atl. & Arct. Oc., Philos. Transact., CLV. p. 409, Pl. XVII. Fig. 89.

Too nearly allied to the type to deserve separate denomination. The chief difference from *serrata* consists in its deficiency of marginal crenulation, instead of which the last two segments are bordered with a smooth limbation. It is generally more ventricose than the type. The emargination of the posterior end of the margin is a common feature with *serrata*, as also the oval or circular aperture.

With the following variety in both seas.

2. **B. serrata** Brady.

B. depressa var. *serrata* Br., 1884, Chall. Rep., IX. p. 146, Pl. III. Fig. 3.
B. serrata Schlumb., 1884, Golfe de Gascogne, Feuilles Jeunes Natur., XIII. Pl. III. Fig. 3; Biloc. gr. fonds, 1891, Mém. Soc. Zool. Fr., IV. Pl. IX. Figs. 50, 51.
B. serrata Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 120, Pl. XXV. Fig. 926.

Distinguished by its crenulated margins of the last two segments and its more or less circular aperture. The crenulation is sometimes very obsolete, and the form of the aperture and the emargination of the posterior end are the only features that may distinguish it from the type. Such a variety is exhibited in Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, Pl. X. Figs. 366, 367, and by Brady, Chall. Rep., IX. Pl. II. Fig. 15.

Pacific. 1000–1200 fathoms.
Caribbean Sea. 200–1000 fathoms.

3. **B. obesa** Reuss. Plate IX. Figs. 3, 4.

B. obesa Reuss, 1864, Oberoligocan, Wien. Ak. Sitz. Ber., L. p. 450, Pl. V. Fig. 7.
? *B. oblonga* d'Orb., For. Cuba, 1839, p. 163, Pl. VIII. Figs. 21–23.
? *M. (Bil.) ringens* Park. & Jones, 1865, (*ex parte*,) North Atlantic & Arct. Oc., Philos. Transact., CLV. p. 409, Pl. XV. Fig. 42.

Exhibits one of the several intermediate forms between *simplex* and *depressa*. Not seldom it assumes an oblong shape and merges into *B. elongata* d'Orb. The aperture is usually a more or less straight or even a ◡ formed slit; the margin is more rounded and less prominent than in *B. simplex*.

Pacific. 772–885 fathoms.
Gulf of Mexico. 769 fathoms.

B. saccata Goës.

Plate IX. Figs. 5–8.

B. saccata Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 121, Pl. XXV. Fig. 928.

A marginally compressed usually tubulate form, with the last segment flask-shaped. The penultima segment often has its margin detached from the last one, leaving to appearance a good deal of the antepenultima segment; the aperture is nearly round on a short neck, and often with bifurcated tongue. The surface is not so much polished as usually in some of its congeners. Length 1.10 mm.

Caribbean Sea. 320 fathoms (Goës).

B. quadrangularis Goës.

Plate IX. Figs. 9–12.

B. quadrangularis Goës, 1894, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 121, Pl. XXV. Fig. 929.
Goës, 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Akad. Hdl., XIX. 4, Pl. IX. Figs. 348, 349.

This singular Biloculina has not been met with in the "Albatross" dredgings, but in my own collections from the Caribbean Sea a few samples are extant. Its marginal section has a tetragone circumference, and often the margin of the last two segments is carinate, the back of these being provided with one or two converging keels and often somewhat scooped out; the aperture short fibula-formed. Length 1 mm.

Caribbean Sea. 320 fathoms (Goës).

VERTEBRALINA d'Orb.

V. conico-articulata Batsch.

Nautilus conico-articulatus Batsch., 1791, Conchyl. Seesandes, p. 3, Pl. III. Fig. 11.
Articulina nitida d'Orb., Tab. Méth., An. Sc. Nat., VII. p. 300, No. 1, Mod. 22.

V. conico-articulata Goës (partly), Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 121, Pl. IX. Fig. 317, 317 *b*.
Articulina conico-articulata Br., 1884, Chall. Rep., IX. p. 185, Pl. XII. Figs. 17, 18, Pl. XIII. Figs. 1, 2.

Is often met with in a pygmy form. There is no need to separate those forms of this family which have a narrow linear build from those which have a more flattened outspread form; the former were by d'Orbigny distinguished as *Articulinæ*, the latter as *Vertebralinæ;* the former should have *milioline*, the latter *hauerine* origin.

Caribbean Sea. 300 fathoms (Goës).

V. Sagra d'Orb.

Articulina Sagra d'Orb., 1839, Cuba, p. 183, Pl. IX. Figs. 23–26 (more narrow).
Vertebralina cassis, mucronata, Ibid. pp. 51, 52, Pl. VII. Figs. 14–19 (broader).
Vertebral. conico-articulata Goës (partly), 1882, Ret. Rhizop. Caribb. Sea, Sv. Vet. Ak. Hdl., XIX. 4, p. 121, Pl. IX. Figs. 311–316.
Articulina Sagra Br., 1884, Chall. Rep., IX. p. 184, Pl. XII. Figs. 22–24.

Attains somewhat higher development and varies highly in the relation between length and breadth. The larval stage is often smooth.

Caribbean Sea. 300 fathoms (Goës).

ORBICULINA d'Orb.

O. adunca Ficht & Moll.

Nautilus aduncus, orbiculus, angulatus F. & M., 1803, Test. Microsc., Pl. XXI.–XXIII.
O. numismalis d'Orb., 1826, Tab. Méth., An. Sc. Nat., VII. p. 305, No. 1. Pl. XVII. Figs. 8–10.
O. adunca Br., 1884, Chall. Rep., IX. p. 209, Pl. XIV. Figs. 1–13.

Attains comparatively large dimensions in the Caribbean Sea, where it is a very common shallow-water form. *Orbiculina* is only an evolutionary stage between *Peneroplis* and *Orbitolites*, and keeps about the same position as *Triloculina* on one side to *Quinqueloculina* and on the other side to *Biloculina*.

Caribbean Sea. 10–300 fathoms; common.

ORBITOLITES.

O. marginalis Lmck.

Orbulites marginalis (Lmck., 1816), Carpenter, 1856, Monogr. Gen. Orbitolites marg., Philos. Transact., CXLVI. p. 192, Pl. IX. Figs. 1, etc.
O. marginalis Br., 1884, Chall. Rep., IX. p. 214, Pl. XV. Figs. 1–5.

Has about the same range of distribution as the preceding, of which it may be considered as a megalaspheric form.

Caribbean Sea, with the preceding.

BATHYMETRICAL DISTRIBUTION ON BOTH SIDES OF THE ISTHMUS.

Fathoms.	Pacific.															Caribbean Sea and Gulf of Mexico.																		
	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	20	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
Astrorhiza crassatina Brady	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" angulosa Brady	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" granulosa Brady	.	.	.	▬	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.
" furcata Goës	.	.	▬	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.
" vermiformis Goës	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.
" tenuis Goës	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhizammina algæformis Brady	.	.	.	.	.	.	.	▬	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" indivisa Brady	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.
Rhabdammina abyssorum M. Sars	.	.	▬	.	▬	.	.	▬	.	.	.	.	.	.	.	.	▬	▬	.	▬	.	.	.	▬	.	▬	.	.	▬	.	.	.	.	.	.	.
R. abyssorum M. Sars., var. irregularis Carp.	.	.	.	.	▬	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" " " linearis Brady	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.
" " " discreta Brady	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	▬	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.
Hyperammina elongata Brady	.	.	.	▬	.	.	.	▬	.	.	.	.	.	.	.	.	▬	▬	▬	▬	▬	.	.	.	.	▬	.	▬	.	▬	.	▬	.	.	.	.
" " var. friabilis Brady	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" ramosa Brady	.	.	.	▬	.	.	.	▬	.	.	.	.	.	.	.	.	▬	.	.	▬	.	.	.	▬	.	▬	.	▬	.	.	.	.	.	▬	.
Jaculella acuta Brady	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" obtusa Brady	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bathysiphon filiformis M. Sars.	.	▬	▬	▬	▬	.	▬	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" " " var. arenosus	.	.	.	▬	.	.	▬	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" " " " rufus de Folin	.	.	▬	▬	.	.	▬	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crithionina rugosa Goës	.	.	.	▬	.	.	▬	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" lens Goës	.	.	▬	▬	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.
" pisum Goës	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.
" granum Goës, var.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.
Placopsilina bulla Brady	.	.	▬	.	▬	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Verrucina rudis Goës	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Thurammina erinacea Goës	▬	.	▬	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" papillata Brady	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.
Saccammina sphærica M. Sars	.	▬	▬	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.
Haplophragmium canariense d'Orb.	.	▬	.	.	.	▬	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
H. latidorsatum Bornem.	.	▬	▬	.	▬	.	.	▬	.	.	.	.	.	▬	.	.	.	▬	▬	▬	.	.	▬	▬	▬	.	▬	▬	▬	.	▬	▬	.	.	.	.
" " var. nitidum Goës	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	▬	.	▬	.	▬	▬	.	.	▬	.	.	▬	.
H. globigeriniformis Park. & Jones	.	.	▬	.	▬	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.
H. turbinatum Brady, var. helicoideum Goës	.	.	.	▬	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.
H. obsoletum Goës	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	▬	▬	▬	.	▬	▬	.	▬	.	.	.
H. fontinense Terq.	.	▬	▬	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Fathoms.	Pacific.															Caribbean Sea and Gulf of Mexico.																		
	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	20	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
H. fontinense, var. compressum Goës	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	▬	▬	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
H. agglutinans d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.
H. lituolinoideum Goës	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	▬	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.
Reophax scorpiurus Mtfrt.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	▬	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" compressus Goës [1]	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" nodulosus Brady	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.
" dentaliniformis Brady	.	.	▬	.	.	▬	▬	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" bacillaris Brady	.	.	.	.	.	▬	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" insectus Goës	.	▬	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" pilulifer Brady	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" distans Brady	.	▬	.	▬	.	▬	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" procerus Goës	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	▬	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" sabulosus Brady	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" difflugiformis Brady	.	.	.	.	.	.	▬	.	.	▬	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" turbo Goës	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" armatus Goës	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ammodiscus incertus d'Orb.	.	▬	▬	▬	.	▬	.	.	.	.	.	.	.	▬	.	.	.	▬	▬	▬	.	.	▬	▬	▬	.	▬	.	▬	.	▬	.	.	.	▬	.
Trochammina trullisata Brady	.	.	.	▬	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	▬	▬	.	.	.	▬	▬	▬	.	.	.	.	.	▬	.	.	.
" ringens Brady	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	▬	▬	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.
" pauciloculata Brady	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" galeata Brady	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" conglobata Brady	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	▬	.	.	.	.	.	?	.	.	.	.	.	.	.
" proteus Karrer	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	▬	.	.	▬	.	▬	▬	.	.	▬	▬	.	▬	.	.	.	.
Hormosina globulifera Brady	.	.	▬	▬	.	▬	▬	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" ovicula Brady, var.	.	▬	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	▬	.	.	.	.	.	.	▬	▬	.	▬	.	.	.	.	.	.	.
" Carpenteri Brady	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.
Webbina clavata	.	▬	▬	.	▬	.	▬	.	.	.	.	.	.	.	.	.	.	.	▬	▬	.	▬	▬	▬	.	▬	.	▬	.	.	▬	.	.	.	.	.
Cyclammina cancellata Norm.	▬	▬	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	▬	▬	▬	▬	.	▬	.	.	.	.	.	▬	.	.	.	.	.	.	▬	.
" pusilla Brady	.	▬	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	▬	.	▬	.	.	.	▬	▬	▬	.	.	.	▬	.	.	.	.	.
Valvulina fusca Will.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	▬	▬	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clavulina communis d'Orb.	.	▬	.	▬	.	▬	.	.	▬	.	.	.	.	.	.	▬	.	.	▬	.	▬	.	▬	.	.	.	▬	.	.	.	.	.	.	.	.	.
" eocœna Gümb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	▬	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬
" parisiensis d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	▬	▬	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" " var. textularioidea Goës	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	▬	▬	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" angularis d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

[1] Omitted in the text. See Goës, Arct. & Scand. Foramf., Sv. Vet. Ak. Hdl., XXV. 9, p. 27, Pl. VI. Figs. 203-210.

	Pacific.																Caribbean Sea and Gulf of Mexico.																	
Fathoms.	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900		20	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
Clavulina rudis Costa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	▬	▬	▬															
" Soldanii Park. & Jones	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		▬	.	▬	▬															
Verneuilina propinqua Brady	.	.	▬	.	▬	.	.	.	.	.	.	.	.	.	.		.	▬	.	▬	▬	.	.	.	.	.	.	.	.	.					
" " var. inflata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	▬	.	.	.	.	.	.	.	▬	.	▬					
" cretacea Karrer	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	▬	▬														
" pusilla Goës	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.														
" triquetra Münster	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	▬	▬	▬															
Tritaxia tricarinata Reuss	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.		.	.	.	▬															
Gaudryina rugosa d'Orb.	.	.	▬	▬	.	.	▬	.	.	.	.	.	.	.	.		.	.	.	▬	▬	▬	.	▬	.	▬	▬	▬	.	▬					
" pupoides d'Orb.	.	.	.	.	.	.	▬	▬	.	.	.	.	.	.	.		.	.	▬	▬	.														
" " var. subrotundata Br.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	▬	▬	▬														
" " " prælonga Karrer	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	▬	▬	▬														
" scabra Brady	.	▬	▬	.	▬	.	.	.	.	.	.	.	.	.	.		.	.	.	▬	▬														
" chilostoma Reuss	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.															
Textularia agglutinans d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	▬	▬	▬															
" sagittula, var. cuneiformis d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	▬															
" luculenta Brady	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	▬															
" concava Karrer	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	▬															
" solita Schwag., var.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.		.	.	.	.															
" lævigata d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	▬	▬	▬															
" rugosa ? Reuss	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	▬	▬	▬															
" conica d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	▬	▬	▬	▬														
" trochus d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	▬	▬															
Bigenerina capreolus d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	▬															
" pennatula Batsch.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	▬															
" nodosaria d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	▬															
Bulimina pyrula d'Orb.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	▬														
" ellipsoides Costa	.	▬	▬	▬	▬	.	.	▬	▬	.	.	.	.	▬	.		.	.	▬	.	.	▬	.	.	.	▬	.	.	.	.	.	.	.	.	.
" aculeata d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.
" inflata Seg.	.	▬	.	.	▬	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	▬	.	▬	▬	.	.	.	.	.	.	.	.	.	.
" elegantissima d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.
Virgulina squamosa d'Orb.	.	.	▬	▬	▬	.	.	▬	.	.	.	.	.	.	.		.	.	.	▬															
" " var. subsquamosa Egger	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.		.	.	.	.															
" subdepressa Brady	.	▬	▬	.	.	.	.	▬	.	.	.	.	.	.	.		.	.	.	.															
Bolivina punctata d'Orb.	.	▬	▬	.	.	.	.	▬	.	.	.	.	.	▬	.		.	.	.	▬															

	Pacific.																Caribbean Sea and Gulf of Mexico.																	
Fathoms.	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900		20	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
Bolivina dilatata Reuss	.	▬	.	.	.	.	.	.	▬	.	.	.	.	.	.		.	.	.	▬															
" Beyrichi Reuss	.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.		.	.	.	▬															
" plicata d'Orb.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.															
" costata d'Orb.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.															
" caribæa Goës	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	▬															
Cassidulina subglobosa Brady	.	.	▬	.	▬	.	.	▬	.	.	.	.	.	.	.		.	.	.	▬	▬	▬	.	.	.	.	▬	▬	.	.	.	.	.	.	.	.
" Bradyi Norman	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	▬															
Ehrenbergina serrata Reuss, var. trigona Goës	.	.	.	.	.	.	▬	▬	▬	.	.	.	.	.	.		.	.	.	▬															
Chilostomella ovoidea Reuss	.	▬	▬	▬	▬	.	▬	▬	.	.	.	.	.	▬	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬
Uvigerina Auberiana d'Orb.	.	▬	▬	.	▬	.	.	▬																											
" " var. lævis Goës	.	▬	.	.	.	.	▬	▬	.	.	.	.	.	.	.		.	.	.	▬															
" pygmæa d'Orb.	.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.		.	.	▬	▬															
" " var. aculeata d'Orb.	.	.	▬	.	.	.	.	▬	.	.	.	.	.	▬	.		.	.	.	.															
Sagrina pygmæa Goës	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	▬															
Lagena lævis Walk. & Boys.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.																				
" " var. tuberculata Karrer	.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.																				
" striata Will.	.	▬	.	.	.	.	▬	.	.	.	.	.	.	.	.																				
" marginata Walk. & Jac.	.	▬	.	.	▬	.	.	▬	.	.	.	.	.	.	.		.	.	▬	▬	.	▬	.	▬	▬										
" " var. staphyllearia Schwag.	.	.	.	.	▬	.	.	▬	.	.	.	.	.	.	.																				
" Orbignyana Seg., var. elongata Goës	.	.	.	.	.	.	▬	▬	.	.	.	.	.	.	.																				
" danica Madsen	.	.	.	.	.	.	▬	▬	.	.	.	.	.	.	.																				
" formosa Schwag.	.	.	.	.	.	.	.	.	.	.	.	.	▬	.	.		.	.	.	.	.	.	.	▬	.										
" seminiformis Schwag.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.																				
" gracilima Seg.	.	.	▬	.	.	.	▬	.	.	.	.	.	.	.	.		.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.	.	.	.	▬
" distoma Park. & Jones	.	.	▬	.	.	.	▬	▬	.	.	.	.	.	.	.																				
Polymorphina lactea d'Orb.	.	.	.	▬	.	.	.	.	.	.	.	.	.	.	.																				
Cristellaria cultrata Lmck.	.	▬	▬	▬	▬	.	.	▬	.	.	.	.	.	.	.		▬	▬	▬	▬	▬	.	.	▬	.	▬	.	.	.	.	.	.	▬	.	▬
" calcar L.in.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		▬	.	.	▬	▬														
" vortex F. & M.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	▬	.	.															
" crepidula F. & M.	.	.	.	.	.	.	▬	▬	.	.	.	.	.	.	.		.	.	▬	.	▬														
" subarcuata Mont.	.	.	.	▬	.	.	▬	▬	.	.	.	.	.	.	.		.	.	.	▬	▬	.	.	.	.	.	.	▬	.	.	.	.	.	.	.
" gibba d'Orb.	.	.	.	.	.	.	▬	.	.	.	.	.	.	.	.		.	.	▬																
" cassis F. & M., var. marginata d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	▬	▬																
" aculeata d'Orb., var.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	▬	▬	.	▬														
" ensiformis Goës	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	▬																

Fathoms.	Pacific.																Caribbean Sea and Gulf of Mexico.																	
	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900		20	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
Cristellaria variabilis Reuss	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.														
" italica Defr.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.														
Vaginulina lævigata Roem.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.														
" glabra d'Orb.	.	.	.	.	.	.	—	.	.	.	.	.	.	.	.		.	.	.	.	.	.														
" linearis Montag.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		—	.	.	.	.	.														
Nodosaria lævigata d'Orb.	.	.	—	—	.	.	—	.	.	.	.	.	.	.	.		.	.	.	—	.	.														
" radicula Lin.	.	.	.	.	.	.	.	—	.	.	.	.	.	.	.		.	.	.	—	—	.														
" comata Batsch	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	—	—	.														
" scalaris Batsch	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	—	—	.														
" communis d'Orb.	.	.	.	.	.	.	—	.	—	.	.	.	.	—	.		.	.	—	—	—	—	.	.	.	.	.	.	.	.	.	.	.	.	—	.
" pauperata d'Orb.	.	.	.	—	.	.	—	—	.	—	.	.	—	.	.		.	.	—	—	—	—	.	.	.	.	.	.	—	.	.	.	.	.	.	.
" Boueana d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		—	.	.	—	—	—	.	.	.	.	.	.	.	.	—	.	.	.	.	.
" soluta v. Reuss	.	.	.	.	—	.	—	—	.	.	.	.	.	.	.		.	—	—	.	—	.	—	—	.	.	.	.	.	.	.	.	.	.	.	.
" lineolata Goës	.	.	.	.	—	.	.	.	.	.	.	.	.	.	.		.	—	—	—	.	.	—	—	.	.	.	.	.	.	.	.	.	.	.	.
" monile Sold.	.	.	.	—	—	.	.	—	.	.	.	.	.	.	.		.	—	—	—	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" hispida d'Orb.	.	.	.	—	.	.	—	—	.	.	.	.	.	.	.		.	—	—	—	—	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" obliqua Linn.	.	.	.	—	.	.	—	.	.	.	.	.	.	.	.		.	—	—	—	—	.	.	.	.	.	.	—	.	.	.	.	.	.	.	.
" seminuda Reuss	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	—	—	—	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" raphanistrum Lin., var. obsoleta Goës	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	—	—	—	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
" raphanus Lin.	.	—	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	—	.	.														
" striolata Goës	.	.	.	.	.	.	.	.	.	.	.	.	—	.	.		.	.	.	—	.	.														
Rhabdogonium tricarinatum	.	.	—	.	.	.	.	.	.	.	.	.	.	.	.		—	—	—	—	.	—														
Lingulina carinata d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	—	.	.	.														
Frondicularia alata d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	—	.	.	.														
Globigerina bulloides d'Orb.	pelagic																pelagic																		
" sacculifera Brady	pelagic																pelagic																		
" rubra d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		pelagic																		
" dubia Egger	pelagic																																		
" æquilateralis Brady	pelagic																pelagic																		
" conglobata Brady	pelagic																pelagic																		
Hastigerina pelagica d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		pelagic																		
Sphæroidina dehiscens Park. & Jones	.	.	—	—	—	.	.	—	—	.	.	.	.	.	.		.	—	.	.	.	.	—	.	.	.	.	.	—	.	.	.	.	.	—	.
" bulloides d'Orb.	pelagic																pelagic																		
Candeina nitida d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		pelagic																		
Pullenia obliqueloculata Park. & Jones	pelagic																pelagic																		

Fathoms.	Pacific.																Caribbean Sea and Gulf of Mexico.																	
	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900		20	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
Pullenia quinqueloba Reuss	.	.	.	.	.	.	—	—	.	.	.	.	.	.	.		.	.	—	—	.	.														
" sphæroides d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	—	—	.														
Planorbulina lobatula Walk. & Jac.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	—	—	.														
" Ungeriana d'Orb.	.	—	.	.	.	.	.	.	.	.	.	.	.	.	.		.	—	—	—	—	.	—	.	.	—	.	.	.	.	.	.	.	.	.	.
" mundula Park. & Jones	.	.	.	.	.	.	—	—	.	.	.	.	.	.	.		.	.	.	—	—	.														
" rudis Gümb.	.	.	—	.	—	.	—	—	.	.	.	.	.	.	.		.	.	—	—	—	.														
" ammonoides Reuss	.	.	.	.	.	.	.	.	.	—	.	.	.	.	.		.	.	.	—	—	.														
" farcta Ficht. & Moll.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	—	—	.														
" Wüllerstorfi Schwag.	.	—	—	—	—	.	.	—	.	.	.	.	.	.	.		.	.	.	.	.	.	—	.	.	.	.	.	.	.	.	.	.	—	.	.
" mediterranensis d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	—	—	.														
" ariminensis d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	—	.	.	.	—														
" reticulata Czjz.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	—	.	.														
" Robertsoniana Brady	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	—	.	.	.	.	.	.	.	.	.	.	.	.	.	—	.	.
Carpenteria proteiformis Goës	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	—	.	.														
Rupertia stabilis Wall.	.	.	—	.	.	.	.	.	.	.	.	.	.	.	.		—	—	.	.	.	.														
Gypsina vesicularis Park. & Jones, var.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		—	—	.	.	.	.														
Polytrema miniaceum Lin.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	—	—	.	.	.														
Pulvinulina repanda Ficht. & Moll.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	—	.	.	—	.														
" exigua Brady	.	.	.	.	.	.	.	—	.	.	.	.	.	.	.		.	.	.	.	.	.														
" Menardii d'Orb.	pelagic																pelagic																		
" Micheliniana d'Orb.	pelagic																pelagic																		
" crassa d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		pelagic																		
" elegans d'Orb.	.	—	—	—	—	—	.	—	.	.	.	.	.	—	.		.	.	.	—	—	—	.	—	.	—	.	.	—	.	.	.	.	—	.	.
" Schreibersii d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	—	.	—	.	—	.	—	.	—	.	.	—	.	.	.	.	.	.	.
" pauperata Park. & Jones	.	.	—	—	—	—	—	.	.	.	.	.	.	.	.		.	.	.	—	—	—	.	—	.	—	.	—	—	.	—	.	.	.	—	.
" auricula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	—	.	—	—	—	.	—	.	—	.	.	—	.	.	.	.	.	—	.
" Hauerii d'Orb., var. semiplecta Schw.	.	.	.	.	.	.	.	—	.	.	.	.	.	.	.		.	.	—	—	.	.														
Discorbina orbicularis Terqu.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	—	—	.	.														
" valvulata d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	—	.	.														
" Berthelotiana d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	—	.	.														
Rosalina Poëyi d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	—	.	.														
" bulloides d'Orb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	—	.	.														
Rotalina Soldanii d'Orb.	.	—	.	—	.	—	.	.	.	.	.	.	.	.	.		.	.	.	—	.	—	.	.	—	.	—	.	.	.	.	.	.	.	.	.
Polystomella striatopunctata Ficht. & Moll.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	—														
Nonionina umbilicatula Montag.	.	.	.	.	—	.	.	—	.	.	.	.	.	.	.		.	.	.	.	.	.														

	Fathoms.	Pacific.																			Caribbean Sea and Gulf of Mexico.																			
		500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	20	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
Nonionina depressula Walk. & Jac.																																								
" scapha Ficht. & Moll.																																								
Amphistegina vulgaris d'Orb.																																								
Heterostegina depressa d'Orb.																																								
Cornuspira foliacea Phil.																																								
Spiroloculina asperula Karrer																																								
" robusta Brady																																								
" canaliculata d'Orb.																																								
Sigmoilina sigmoidea Brady																																								
" celata Costa																																								
Miliolina seminulum Lin.																																								
" circularis Bornem.																																								
" procera Goës																																								
" bicostata d'Orb.																																								
" polygona d'Orb.																																								
" contorta d'Orb.																																								
" consobrina d'Orb.																																								
" tricarinata d'Orb.																																								
Biloculina sphæra d'Orb.																																								
" irregularis d'Orb.																																								
" bulloides, var. simplex d'Orb.																																								
" abyssorum																																								
" comata Brady																																								
" insignis Brady																																								
" tubulosa Costa																																								
" depressa d'Orb.																																								
" " var. serrata Brady																																								
" " " murrhina Schwag.																																								
" obesa Reuss																																								
" quadrangularis Goës																																								
" saccata Goës																																								
Vertebralina conico-articulata Batsch																																								
" Sagra d'Orb.																																								
Orbiculina adunca Ficht. & Moll.																																								
Orbitolites marginalis Lmck.																																								

RECORD OF SUBMARINE TOW-NET STATIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS."*

MARCH AND APRIL, 1891.

Serial Number.	DATE.	TIME.	POSITION. Latitude North.	POSITION. Longitude West.	TEMPERATURES. Surface.	TEMPERATURES. Bottom.	Depth in Fathoms.	Character of Bottom.	Depth at which towed, in Fathoms.	Time in Minutes.	REMARKS.
	1891.	h. m.	° ′ ″	° ′ ″	°	°					
3382 Dr.	March 7	8 50 A.M.	6 21 0	80 41 0	75	35.8	1793	gn. M.	200	15	
"	" 7	9 53 A.M.	6 21 0	80 41 0	75	35.8	1793	gn. M.	200		Hauled up straight from 200 fathoms in 10 minutes; from 100 fathoms, in about 5 minutes. About 60 miles from the 100 fathom line.
"	" 7	10 23 A.M.	6 21 0	80 41 0	75	35.8	1793	gn. M.	100		
3388 Dr.	" 9	10 31 A.M.	7 6 0	79 48 0	73	36.2	1168	gn. glob. Oz.	400	17	15 miles from 100 f. line, and 25 miles from nearest land.
2619 Hyd.	" 11	8 25 A.M.	7 31 0	78 42 30	68	36.5	1100	gn. glob. Oz.	300	19	
"	" 11	9 44 A.M.	7 31 0	78 42 30	68	36.5	1100	gn. glob. Oz.	1000 to 1482 †	16	Drifted into 1482 fathoms.
2627 Hyd.	" 25	6 49 A.M.	0 36 0 *South.*	82 45 0	81	36.0	1832	gy. glob. Oz.	1770 to 1789 †	20	
2628 Hyd.	" 26	9 14 A.M.	0 13 0 *North.*	84 52 0	81	—	—	——	204	20	Towed awhile from 200 fathoms to surface, to fill upper part of net. About 250 m. from the Galapagos.
3414 Dr.	April 8	6 57 A.M.	10 14 0	96 28 0	82	35.8	2232	gn. M.	100	20	350 miles from land.
"	" 8	7 47 A.M.	10 14 0	96 28 0	82	35.8	2232	gn. M.	200	10	
"	" 8	8 49 A.M.	10 14 0	96 28 0	82	35.8	2232	gn. M.	300	20	
"	" 8	10 30 A.M.	10 14 0	96 28 0	82	35.8	2232	gn. M.	300	15	
——	" 9	10 4 A.M.	12 34 0	97 21 0	82	—	—	——	175	8	About 300 miles S. E. of Acapulco. Depth.‡
——	" 9	8 3 P.M.	13 33 30	97 57 30	83	—	—	——	175	10	About 250 miles S. E. of Acapulco. Depth.‡
——	" 11	8 45 A.M.	16 32 0	99 42 0	80	—	—	——	200	20	About 30 miles S. E. of Acapulco. Depth.§
——	" 16	10 10 A.M.	17 39 30	102 11 30	76	—	—	——	175	15	About 120 m. N. W. of Acapulco. Depth over 2,000 f.
3436 Dr.	" 22	1 22 P.M.	27 3 40	110 53 40	72	37.2	905	bn. M. bk. Sp.	800	15	Surface about 75 miles S. W. of Guaymas, halfway across Gulf of California.
2637 Hyd.	" 22	7 21 P.M	27 20 0	110 54 0	71	38.0	773	bn. M. bk. Sp.	700	15	About 50 miles S. W. of Guaymas.
3437 Dr.	" 23	5 31 A.M.	27 39 40	111 0 30	70	40.0	628	bn. M. bk. Sp.	600	15	Shoaled water and dragged on bottom.
2638 Hyd.	" 23	7 26 A.M.	27 38 0	111 4 0	72	39.2	622	bn. M. bk. Sp.	500 to 570 †	15	

* Tanner tow-net at all Stations except Station 3282, March 7.

† Depth varying between these points.

‡ Between two Stations, over 2,000 fathoms.

§ Between two Stations, about 500 fathoms.

RECORD OF DREDGING AND TRAWLING STATIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS."

Serial Number.	DATE.	TIME.	POSITION. Latitude North.	POSITION. Longitude West.	TEMPERATURES Surface.	TEMPERATURES Bottom.	Depth in Fathoms.	Character of Bottom.	REMARKS
	1891.	h. m.	° ′ ″	° ′ ″	°	°			
	Feb. 22	8 0 P.M.	—	—	—	—	—	—	
3353	Feb. 23	8 56 A.M.	7 6 15	80 34 0	73	39.0	695	gn. M.	Surface tow-net.
3354	" 23	1 25 P.M.	7 9 45	80 50 0	78	46.0	322	gn. M.	Surface tow-net.
3355	" 23	3 1 P.M.	7 12 20	80 55 0	81	54.1	182	bk. G. Sh.	
3356	" 23	7 30 P.M.	7 9 30	81 8 30	83	40.1	546	sft. bl. M.	Surface tow-net 15 miles from Mariato Point.
3357	" 24	6 17 A.M.	6 35 0	81 44 0	83	38.5	782	Modern Greensand.	Surface tow-net.
3358	" 24	11 38 A.M.	6 30 0	81 44 0	83	40.2	555	Modern Greensand.	
3359	" 24	2 4 P.M.	6 22 20	81 52 0	83	42.0	465	Rky.	
3360	" 24	5 20 P.M.	6 17 0	82 5 0	83	36.4	1672	fne. bk. dk. gn. S.	
3361	" 25	7 33 A.M.	6 10 0	83 6 0	82	36.6	1471	gn. Oz.	Surface tow-net.
3362	" 26	7 20 A.M.	5 56 0	85 10 30	84	36.8	1175	gn. M. S. rky.	
3363	" 26	4 37 P.M.	5 43 0	85 50 0	83	37.5	978	wh. glob. Oz.	Intermediate net of Chun and Peterson.
3364	" 27	6 58 A.M.	5 30 0	86 8 30	81	38.0	902	yl. glob. Oz.	Surface tow-net.
3365	" 27	1 30 P.M.	5 31 0	86 31 0	85	37.0	1010	yl. glob. Oz.	
3366	" 27	8 4 P.M.	5 30 0	86 45 0	84	37.0	1067	yl. glob. Oz.	Surface tow-net.
3367	" 28	6 38 A.M.	5 31 30	86 52 30	82	57.1	100	Rky.	
3368	" 28	7 21 A.M.	5 32 45	86 54 30	82	58.4	66	Rky.	Surface tow-net.
3369	" 28	8 7 A.M.	5 32 45	86 55 20	82	62.2	52	Nullipore or rky.	
3370	" 28	10 3 A.M.	5 36 40	86 56 50	84	54.8	134	Rks. & S.	At Cocos Island. Surface tow-net at night.
3371	March 1	7 49 A.M.	5 26 20	86 55 0	82	39.0	770	glob. Oz.	
3372	" 1	5 51 P.M.	4 49 0	86 11 20	84	38.8	761	gy. glob. Oz.	8 P. M. Surface tow-net.
3373	" 2	10 33 A.M.	4 2 0	84 58 0	82	36.6	1877	br. M. bk. sp.	
3374	" 3	10 35 A.M.	2 35 0	83 53 0	80	36.4	1823	gn. Oz.	

RECORD OF DREDGING AND TRAWLING STATIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS."— *Continued.*

Serial Number.	DATE.	TIME.	POSITION. Latitude North.	POSITION. Longitude West.	TEMPERATURES. Surface.	TEMPERATURES. Bottom.	Depth in Fathoms.	Character of Bottom	REMARKS.
	1891.	h. m.	° ′ ″	° ′ ″	°	°			
3375	March 4	6 36 A.M.	2 34 0	82 29 0	77	36.6	1201	gy. glob. Oz.	Surface tow-net.
3376	" 4	4 27 P.M.	3 9 0	82 8 0	78	36.3	1132	gy. glob. Oz.	
3377	" 5	8 38 A.M.	3 56 0	81 40 15	77	38.0	764	M.	
3378	" 5	11 45 A.M.	3 58 20	81 36 0	78	55.9	112	brk. sh.	
3379	" 5	2 15 P.M.	3 59 40	81 35 0	78	—	52	Rks.	
3380	" 5	4 51 P.M.	4 3 0	81 31 0	79	37.2	899	Rks.	
3381	" 6	8 38 A.M.	4 56 0	80 52 30	77	35 8	1772	gn. M.	Siphonophore clinging to wire rope.
3382	" 7	10 46 A.M	6 21 0	80 41 0	75	35 8	1793	gn. M.	Submarine tow-net. 8 : 30 P. M., Surface tow-net.
3383	" 8	6 51 A.M.	7 21 0	79 2 0	74	36 0	1832	gr. glob. Oz.	
3384	" 8	1 20 P.M.	7 31 30	79 14 0	74	42 0	458	gn. S.	
3385	" 8	3 7 P.M.	7 32 36	79 16 0	72	45.9	286	gn. M.	
3386	" 8	4 54 P.M.	7 33 12	79 17 15	73	48.0	242	fne. gy. S.	
3387	" 8	7 21 P.M.	7 40 0	79 17 50	74	56.4	127	fne. gy. S.	Surface tow-net.
3388	" 9	6 41 A.M.	7 6 0	79 48 0	73	36 2	1168	gn. glob. Oz.	Submarine tow-net.
3389	" 9	2 10 P.M.	7 16 45	79 56 30	74	48.8	210	gn. M.	
3390	" 9	4 25 P.M	7 26 10	79 53 50	74	62 6	56	fne. gy. S. G.	
3391	" 9	7 15 P.M.	7 33 40	79 43 20	73	55 8	153	gn. M.	
3392	" 10	6 30 A.M.	7 5 30	79 40 0	73	36.4	1270	hard.	Rhabdamina bottom.
3393	" 10	1 21 P.M.	7 15 0	79 36 0	74	36.8	1020	gn. M.	
3394	" 10	5 43 P.M.	7 21 0	79 35 0	73	41.8	511	dk. gn. M.	

RECORD OF DREDGING AND TRAWLING STATIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS. — *Continued.*

Serial Number.	DATE.	TIME.	POSITION. Latitude North.	POSITION. Longitude West.	TEMPERATURES. Surface.	TEMPERATURES. Bottom.	Depth in Fathoms	Character of Bottom.	REMARKS
	1891.	h. m.	° ′ ″	° ′ ″	°	°			
3395	March 11	2 20 P.M.	7 30 36	78 39 0	70	38.5	730	Rky.	
3396	" 11	5 15 P.M.	7 32 0	78 36 30	70	47.4	259	hrd. gy. M. S.	
3397	" 11	6 32 P.M.	7 33 0	78 34 20	71	57.3	85	stf. gn. M. brk. sh.	Surface tow-net.
3398	" 23	3 16 P.M.	1 7 0	80 21 0	84	86.0	1573	gn. Oz.	Surface tow-net, off Galera Point.
3399	" 24	6 37 A.M.	1 7 0	81 4 0	80	36.0	1740	gn. Oz.	Surface tow-net.
			South.						
3400	" 27	6 10 A.M.	0 36 0	86 46 0	81	36.0	1322	lt. gy. glob. Oz.	Surface tow-net, March 25.
3401	" 28	4 45 A.M.	0 59 0	88 58 30	82	44.0	395	glob. Oz.	
3402	" 28	7 13 A.M.	0 57 30	89 3 30	82	42.3	421	R. glob. Oz.	
3403	" 28	10 19 A.M.	0 58 30	89 17 0	82	43.3	384	fne. gy. S. bk. Sp.	
3404	" 28	1 16 P.M.	1 3 0	89 28 0	83	43.2	385	R.	
3405	" 28	3 42 P.M.	0 57 0	89 38 0	83	60.0	53	R. Co. Sh.	Tangles.
3406	April 3	6 47 A.M.	0 16 0	90 21 30	81	41.3	551	R.	
3407	" 3	10 48 A.M.	0 4 0	90 24 30	81	37.2	885	glob. Oz.	Tangles.
			North						
3408	" 3	4 7 P.M.	0 12 30	90 32 30	83	39.5	684	glob. Oz.	Tangles.
3409	" 3	7 24 P.M.	0 18 40	90 34 0	82	42.3	327	bk. S.	Tangles.
3410	" 3	8 48 P.M.	0 19 0	90 34 0	82	44.2	331	bk. S.	Tangles. Surface tow-net. Off Bindloe Island, 4 miles west.
3411	" 4	7 35 A.M.	0 54 0	91 9 0	82	36.2	1189	yl. glob. Oz.	
3412	" 4	6 11 P.M.	1 23 0	91 43 0	82	38.0	918	R.	9 P. M., surface tow-net, 5 m. off Wenman Islands.
3413	" 5	8 31 A.M.	2 34 0	92 6 0	82	36.0	1360	glob. Oz. dk. Sp.	At noon, surface tow-net.
3414	" 8	11 14 A.M.	10 14 0	93 28 0	82	35.8	2232	gn. M.	Submarine tow-net and surface tow-net.
3415	" 10	9 39 A.M.	14 46 0	93 40 0	82	36.0	1879	br. M. glob. Oz.	

RECORD OF DREDGING AND TRAWLING STATIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS." — *Continued.*

Serial Number.	DATE.	TIME	POSITION. Latitude North.	POSITION. Longitude West.	TEMPERATURES. Surface.	TEMPERATURES. Bottom.	Depth in Fathoms.	Character of Bottom.	REMARKS
	1891.	h. m.	° ′ ″	° ′ ″	°	°			
3416	April 11	9 46 A.M.	16 32 30	99 42 40	81	40 5	419	fne. br. M.	
3417	" 11	11 44 A.M.	16 32 0	99 48 0	82	40.6	193	gn. M.	
3418	" 11	2 57 A.M.	16 33 0	99 52 30	82	39 0	660	br. S. bk. Sp.	
3419	" 11	5 59 P.M.	16 34 30	100 3 0	81	39.0	772	gn. M. bk. Sp.	Surface tow-net.
3420	" 12	7 48 A.M.	16 46 0	100 8 20	82	39.6	664	dk. gn. M.	
3421	" 12	11 32 A.M.	16 47 20	100 0 10	82	42.9	388	dk. gn. M.	
3422	" 12	12 35 P.M.	16 47 30	99 59 30	83	53.5	141	gn. M.	
3423	" 12	1 31 P.M.	16 47 30	99 59 20	83	56.0	94	gn. M.	
3424	" 18	11 18 A.M.	21 15 0	106 23 0	76	38.0	676	gy. S. bk. Sp. Glob.	
3425	" 18	2 14 P.M.	21 19 0	106 24 0	76	39.0	680	gn. M. & S.	
3426	" 18	3 45 P.M.	21 21 0	106 25 0	76	51.2	146	Rky.	
3427	" 18	4 3 P.M.	21 22 15	106 25 0	75	51.2	80	Rky.	Tangles.
3428	" 18	6 40 P.M.	21 36 30	106 25 0	76	48.1	238	dk. gy. S. Glob.	
3429	" 19	5 39 A.M.	22 30 30	107 1 0	73	37.0	919	gn. M. Glob. Oz.	
3430	" 19	3 27 P.M.	23 16 0	107 31 0	73	37.9	852	bk. S.	
3431	" 20	6 33 A.M.	23 59 0	108 40 0	70	37.0	995	lt. bro. M. Glob.	
3432	" 20	2 38 P.M.	24 22 30	109 3 20	70	37.8	1421	br. M. bk. Sp.	
3433	" 21	6 34 A.M.	25 26 15	109 48 0	69	36.5	1218	br. M. bk. Sp.	Surface tow-net.
3434	" 21	10 14 A.M.	25 29 30	109 48 0	70	36.4	1588	br. M. bk. Sp.	
3435	" 22	8 56 A.M.	26 48 0	110 45 20	70	37.3	859	br. M. bk. Sp.	
3436	" 22	3 10 P.M.	27 34 0	110 53 40	72	37.2	905	br. M. bk. Sp.	Submarine tow-net and surface tow-net.
3437	" 23	5 4 A.M.			70	40.0	628	br. M. bk. Sp.	Submarine tow-net dragged on the bottom. About 50 miles south of Guaymas.

PLATE I.

Fig. 1. Reophax armatus, n. 2.50 mm.
Fig. 2. " turbo, n. 0.66 mm.
Fig. 3. " " oral aspect.
Fig. 4. Astrorhiza furcata, n., lateral aspect. 5 mm.
Fig. 5. " " marginal aspect.
Fig. 6. Astrorhiza tenuis, n., a broken specimen. 9.5 mm.
Fig. 7. " " transverse section of same.
Fig. 8. " " longitudinal section of same.
Fig. 9. Astrorhiza vermiformis. 13 mm.
Fig. 10. Bathysiphon rufus Folin, n., sandy form. 10 mm.
Fig. 11. " filiformis M. Sars. 22 mm.
Fig. 12. " " transverse section.
Fig. 13. Rhabdammina discreta Br., brittle form. 7 mm.
Fig. 14. " " constructed of sand and sponge spicules.
Fig. 15. Verrucina rudis, n., seen from the opening. 3.2 mm.
Fig. 16. " " side view.

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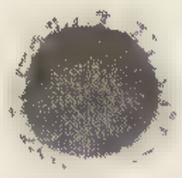

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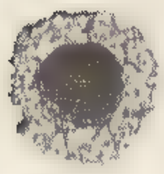

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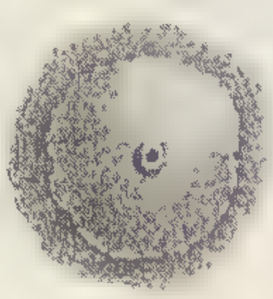

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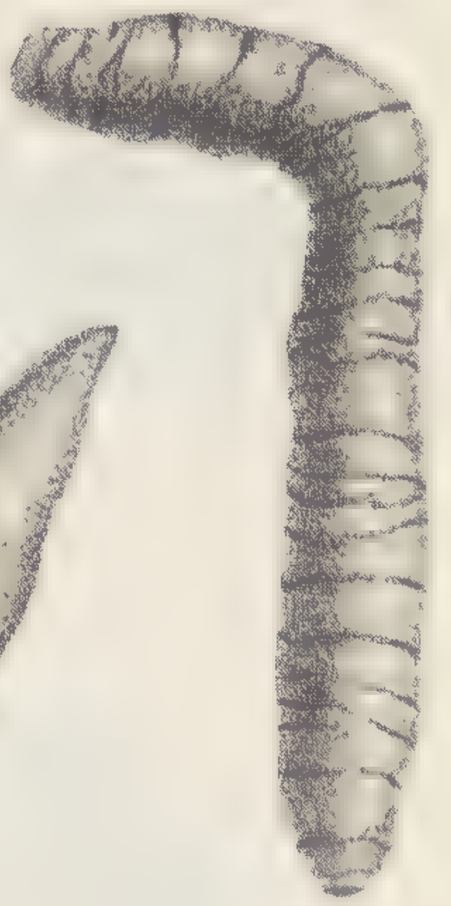

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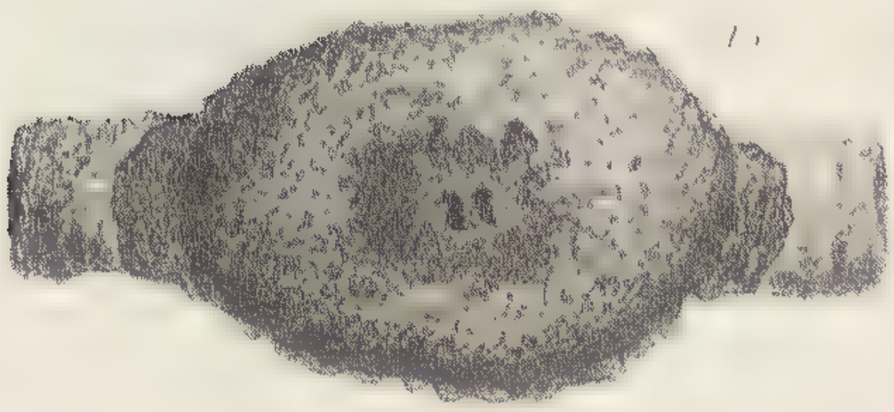

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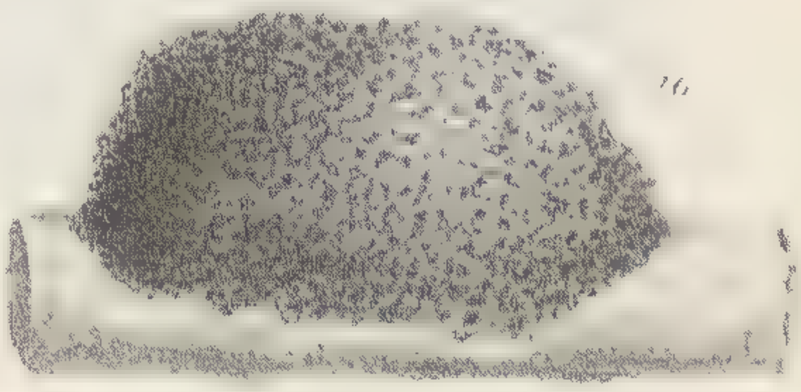

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PLATE II.

Fig. 1. Crithionina pisum, n. 1–3 mm.
Fig. 2. " " median section.
Fig. 3. Crithionina rugosa, n. 2 mm.
Fig. 4. " " median section.
Fig. 5. Crithionina lens, n., marginal view.
Fig. 6. " " lateral view. 4 mm.
Fig. 7. } " " the interior laid open.
Fig. 8. }
Fig. 9. Thurammina erinacea, n. 0.25 mm.
Fig. 10. " " median section.

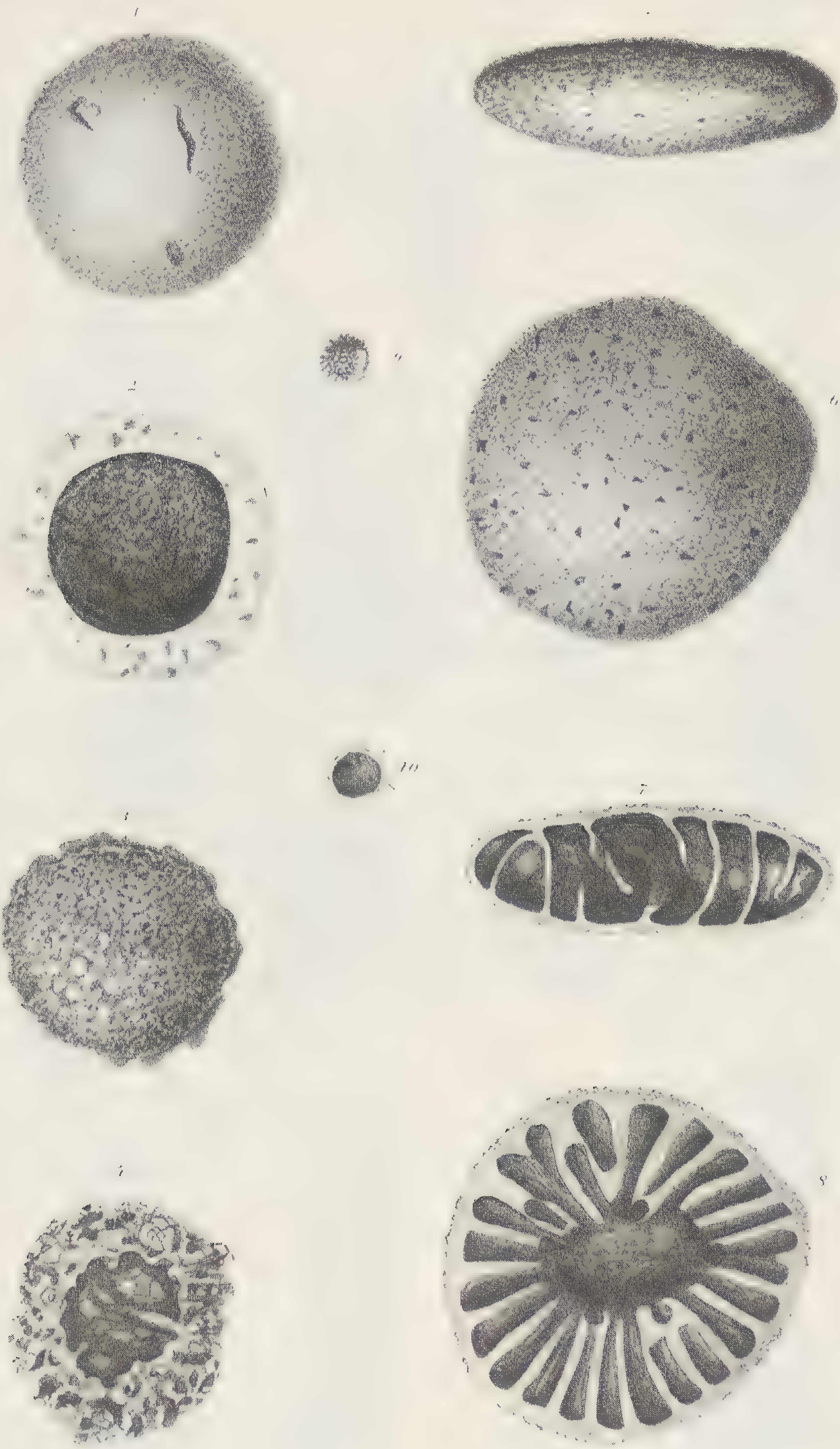

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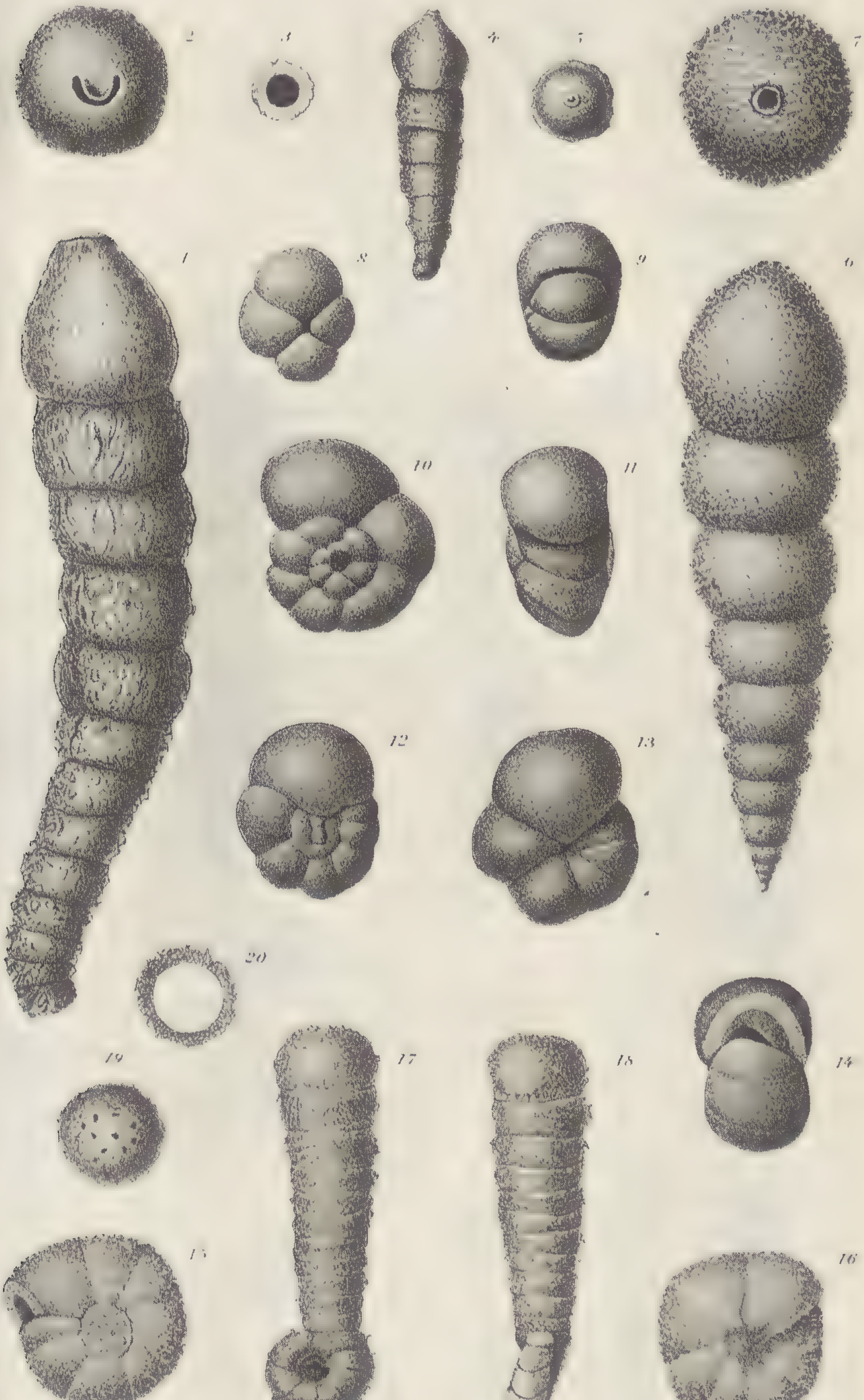
PLATE III.

Fig. 1. Reophax procerus, Goes, side view of a large specimen. 9.0 mm.
Fig. 2. " " " oral side with valvulated aperture.
Fig. 3. " " " transverse section of the primordial segment.
Fig. 4. " " " a pygmy specimen.
Fig. 5. " " " aperture of the same.
Fig. 6. Reophax insectus. 7.20 mm.
Fig. 7. " " oral aspect.
Fig. 8. Haplophragmium latidorsatum Bornem., var. nitidum. 0.70 mm.
Fig. 9. " " marginal oral view.
Fig. 10. Haplophragmium turbinatum var. helicoideum, n. 1.30 mm., aboral side.
Fig. 11. " " " " marginal oral side.
Fig. 12. " " " " with irregular spire.
Fig. 13. " " " " umbilical side.
Fig. 14. Haplophragmium obsoletum, n. 1.20 mm., marginal oral side.
Fig. 15. " " " spiral side.
Fig. 16. " " " umbilical view.
Fig. 17. Haplophragmium lituolinoideum, n., with apertural pores. 75 mm., lateral view.
Fig. 18. " " marginal view.
Fig. 19. " " the top.
Fig. 20. " " transverse section of a chamber.



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B. Meisel lith Boston

PLATE IV.

Figs. 1–3. Hormosina ovicula Br. 3.60–4.80 mm.
Fig. 4. Clavulina rudis Costa, ovoid form. 2.86 mm., oral face with the valvular aperture.
Fig. 5. " " " side view.
Figs. 6–8. " " " valvular apertures of different shape.
Figs. 9, 10. Clavulina communis, v. lævigata, from Caribbean Sea. 1.30–1.50 mm.
Figs. 11–14. " " different arrangement of aperture of oral side.
Fig. 15. " " transverse section of the biserial larval stage.
Fig. 16, 24. Clavulina cocœna Gümb. 2.30 mm.
Figs. 17–21. " " oral sides with different shapes of the aperture.
Fig. 22. " " longitudinal section.
Fig. 23. " " transverse section of a segment showing traces of subdivisional septa.
Fig. 25. " " same section of the larval stage quadriserialis.
Figs. 26, 36, 37. Clavulina parisiensis, textularioidea Goës, three full grown samples from Caribbean Sea.
Fig. 27. " " " longitudinal lateral section.
Figs. 28, 29. " " " marginal view of the compressed larval stage.
Figs. 30–35. " " " oral side with different shapes of aperture.
Fig. 38. " " " section of a younger sample.
Fig. 39. Clavulina Soldanii Park. & Jones, pygmy species. 2.40 mm.
Fig. 40. " " " aperture.
Fig. 41. " " " longitudinal section.
Fig. 42. " " " transverse section of the mature stage.
Fig. 43. " " " transverse section of the larval stage.
Fig. 44. " " " very extenuated sample.
Fig. 45. " " " apertural face with simplified aperture.
Fig. 46. " " " transverse cut of its last segment.

PLATE V.

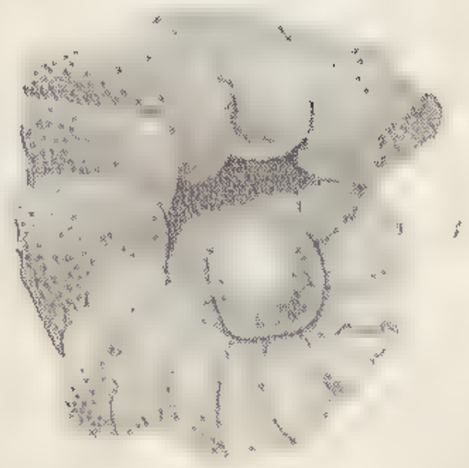
Fig. 1. Textularia solita Schw. var. inflata. 1.45 mm.
Fig. 2. " " " marginal.
Fig. 3. " " " oral view.
Fig. 4. Textularia rugosa Reuss, var. 1.50 mm.
Fig. 5. " " " aperture.
Figs. 6, 7. Verneuilina pusilla, n. 0.55 mm.
Fig. 8. " " aperture.
Fig. 9. Gaudryina rugosa d'Orb. var. 2.20 mm.
Fig. 10. " " " oral face.
Fig. 11. Lagena danica Madsen, n. 0.70 mm.
Fig. 12. " " marginal view.
Fig. 13. Cristellaria cassis, var. marginata d'Orb. 2.00 mm.
Fig. 14. " " " " marginal aspect.
Fig. 15. Cristellaria aculeata d'Orb. var. 2.23 mm.
Fig. 16. " " " marginal aspect.
Fig. 17. Cristellaria ensiformis, n. 3 mm.
Fig. 18. " " marginal view.
Figs. 19, 21, 24. Cristellaria subarcuatula Montag. 3.30–7.50 mm.
Figs. 20, 22, 23. " " " marginal view.

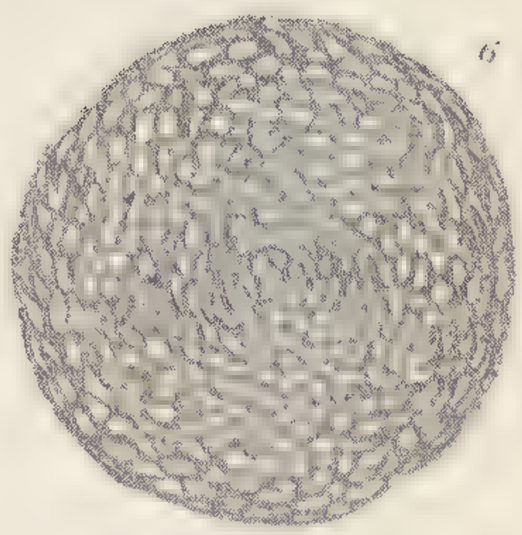
PLATE VI.

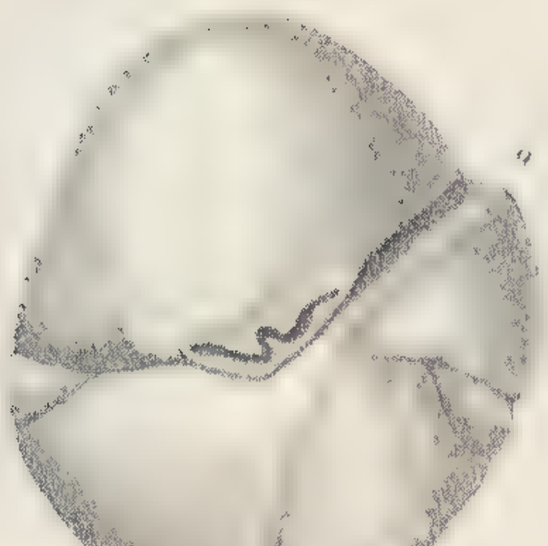
Fig. 1. Nodosaria communis d'Orb., slender form. 6 mm. Dent. badenensis d'Orb.
Fig. 2. " Boueana d'Orb. 7 mm.
Fig. 3. " raphanistrum var. obsoleta. 19 mm.
Fig. 4. " seminuda Reuss. 6.25 mm.
Fig. 5. " " " oral aspect.
Fig. 6. " striolata Goës.
Fig. 7. " " " oral aspect.
Fig. 8. Carpenteria proteiformis Goës, virgulina-formed.
Fig. 9. " " " balani-formed attached specimen.
Fig. 10. " " " another, with additional cluster of inflated segments.
Fig. 11. " " " basal section of a more regular specimen.
Fig. 12. " " " another form with biserial segments and alvostoma tubes.
Fig. 13. " " " the segments and aperture arranged like that of a Bulimina.
Fig. 14. " " " Globigerini-formed apertural side.
Fig. 15. " " " the marginal side.
Fig. 16. " " " a detached large segment with afferent and efferent tubes.
Fig. 17. " " " section of the wall with network of pores.

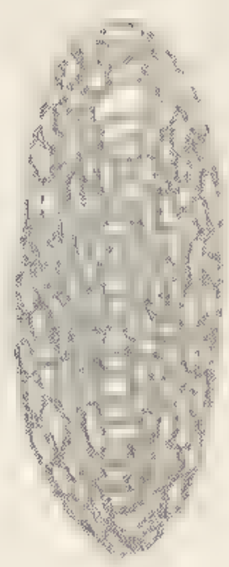
PLATE VII.

Fig. 1. Planorbulina Ungeriana, var. affixa Goës, marginal aspect. 1.20 mm.
Fig. 2. " " " " spiral or aboral side.
Fig. 3. " " " " attached apertural side.
Fig. 4. Gypsina vesicularis var. discus Goës, areolated surface. 3 mm.
Fig. 5. " " " " middle, marginal section.
Fig. 6. " " " " " lateral section.
Figs. 7, 8. Miliolina procera. 2.40 mm.
Fig. 9. " " oral view.
Fig. 10, 12. Miliolina contorta D'ORB. var. 1.80 mm.
Fig. 11. " " " oral view.









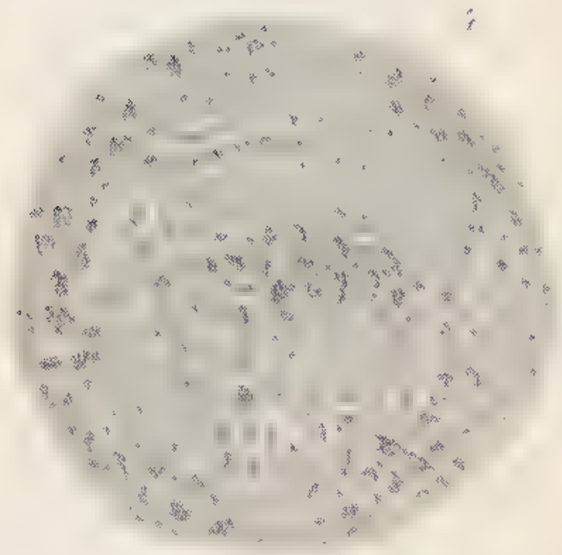


PLATE VIII.

Figs. 1, 3.	Miliolina contorta d'Orb.	2 mm.; from temperate Atlantic.
Fig. 2.	" " "	oral view.
Figs. 4–6.	" " "	short and thick; from temperate Atlantic.
Fig. 7.	" " "	stout form.
Figs. 8–10.	Miliolina concava Reuss;	from western shores of Sweden.
Figs. 11, 12.	Miliolina polygona d'Orb.	1.11–1.50 mm.
Figs. 13, 14.	" " "	transverse sections of the same.
Figs. 15, 16, 18.	" " "	another, stouter sample.
Fig. 17.	" " "	oral view.
Fig. 19.	Miliolina bicostata d'Orb.	1.07 mm.
Figs. 20, 21.	" " "	apertural view of two samples.

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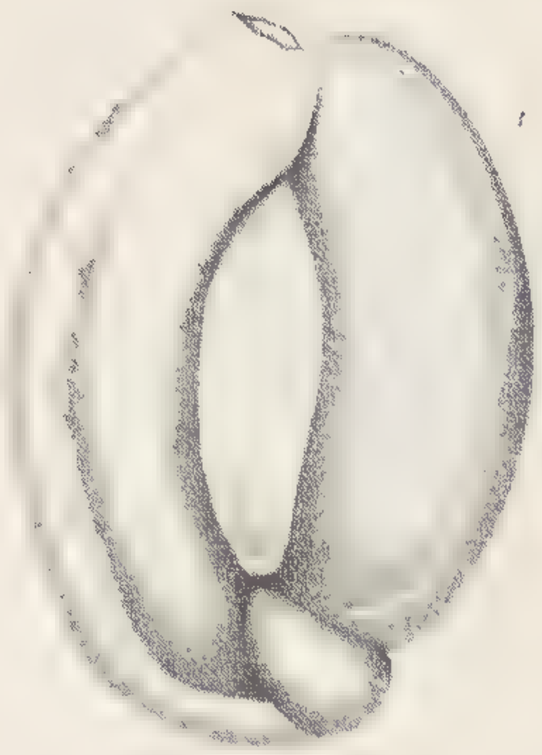
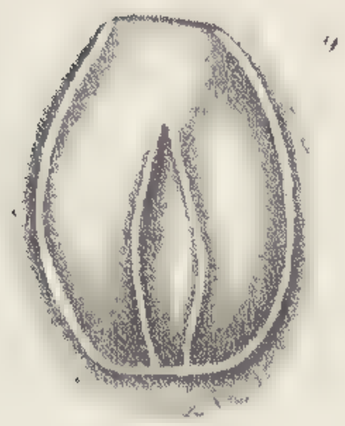
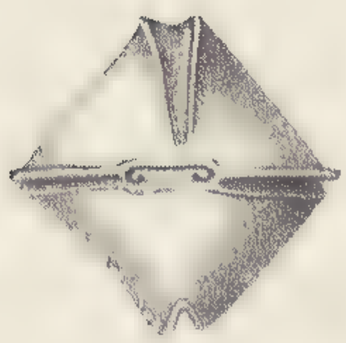
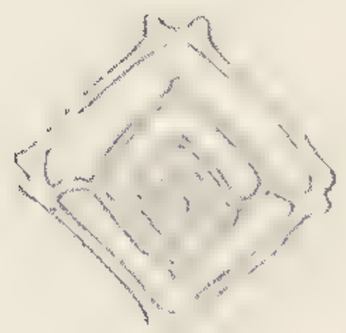


PLATE IX.

Figs. 1, 2. Biloculina abyssorum Goës.
Figs. 3, 4. Biloculina obesa Reuss. 1.80 mm.
Fig. 5. Biloculina saccata Goës. 1.10 mm., oral view.
Fig. 6. " " " side view.
Fig. 7. " " " side view of another sample with dehiscent segments.
Fig. 8. " " " cut through the transversal medial plane.
Fig. 9. Biloculina quadrangularis Goës, the back of the last segment.
Fig. 10. " " " the marginal view.
Fig. 11. " " " the oral end.
Fig. 12. " " " transverse section.







EXPLORATIONS OF THE
U.S. FISH COMMISSION
STEAMER ALBATROSS
Lieut. Comdr. Z. L. Tanner, U.S.N., Comdg.
February to April 1891
Compiled from the latest U. S. Hydrographic Office charts with additions by the U.S.F.C. Steamer Albatross.
Soundings represented thus 2256 are by the U.S.F.C. Str. "Albatross" 1888
" " " 2280 " " " " 1889
" " " 2232 " " " " 1891
" " " 2004 are from other sources
100 fathom line shown thus
500 " "
1000 " "
1500 " "
2000 " "
P Pebbles, Co coral, Gl globigerina, M mud, O ooze, S sand, Sh shells, Sp. specks, G. gravel, fne. fine, hrd. hard, sft. soft, rk. rocky, brk. broken, bk. black, rd. red, gn. green, gy. gray, yl. yellow, br. brown, dk. dark, lt. light, wh. white
Track of the U.S.F.C. Str. "Albatross" 1891
GULF OF MEXICO
MEXICO
GUATEMALA
HONDURAS
SALVADOR
NICARAGUA
COSTA RICA
CARIBBEAN SEA
COLOMBIA
PANAMA
Gulf of Panama
GALAPAGOS ISLANDS
REVILLA GIGEDO ISLANDS
GUAYMAS
Agiabampo
Topolobampo
Altata
MAZATLAN
San Blas
Banderas Bay
C. CORRIENTES
Manzanillo
Maruata
ACAPULCO
P. Angeles
Salina Cruz
TEHUANTEPEC
La Puerta
Champerico
S. Jose
Acajutla
La Libertad
Gulf of Fonseca
Corinto
Gulf of Nicoya
Gulf of Dulce
C. Mala
Choco Bay
Gorgona I.
Malpelo I.
Cocos I.
C. SAN FRANCISCO
C. San Lorenzo
C. Corrientes
C. SAN LUCAS
LA PAZ
C. SAN LAZARO
Magdalena Bay
Concepcion Bay
Socorro
Clarion I.
Culpepper I.
Wenman I.
Abingdon I.
Albemarle I.
Tower I.
Indefatigable I.
Chatham I.
Hood I.
Charles I.
Narborough I.
2000 fathoms
100 fathoms
500 fathoms

Bulletin of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
VOL. XXIX. No. 2.

THE REACTIONS OF METRIDIUM TO FOOD AND OTHER SUBSTANCES.

By G. H. PARKER.

CAMBRIDGE, MASS., U. S. A.:
PRINTED FOR THE MUSEUM.
MARCH, 1896.

No. 2. — *The Reactions of Metridium to Food and other Substances.*[1]

By G. H. Parker.

Introduction. — The observations upon which the following account is based were made at the Newport Marine Laboratory in August, 1895, and it is with great pleasure that I acknowledge my indebtedness to Mr. Alexander Agassiz through whose kindness and generosity I enjoyed the privilege of working there.

The growing interest in the comparative physiology of the nervous system has shown itself in no way more forcibly than in the number and importance of the contributions to this subject in the last decade. These contributions, however, demonstrate the richness of this new field of research rather than its exhaustion, and point to a remodelling of the older physiological conceptions on the grounds of wider observations. It is my purpose in dealing with the relations of actinians to their food to aid in some degree this general advancement.

The stimulation of actinians by their food and other substances has been a matter of study only recently. In 1882 Pollock ('82, p. 474) stated that, when pieces of mussel, limpet, etc., were placed near an actinian in a sea pool or salt-water tank, the animal responded by expanding its oral disk and moving its tentacles. This response was interpreted by Romanes, in an addendum to Pollock's paper, as evidence of a sense of smell in these animals, a conclusion from which Jourdan ('91, p. 131) dissented, in that he preferred to regard the response as a result of the stimulation of the organs of taste.

In none of these earlier investigations was any attempt made to localize the sense organs affected by the food, and it was not till 1891 that Loeb described, in connection with other matters, some experiments bearing upon this question. Loeb ('91, p. 67) studied several genera of actinians, — Adamsia, Actinia, Anemonia, etc., — and demonstrated that, amongst other organs, the tentacles were stimulated by the presence of food. The tentacles, however, were not the only parts capable of

[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy at Harvard College, E. L. Mark, Director, No. LV.

being thus stimulated; for, when an actinian was cut transversely in two, the portion without tentacles still took in meat but refused sand and paper (Loeb, '91, pp. 69, 70).

In the year following that in which Loeb's publication appeared, Nagel ('92, p. 335) described some experiments on what he called the sense of taste in actinians. His work was done apparently without knowledge of the results obtained by Loeb, for he makes no mention of these. This oversight was probably due to the fact that Loeb's studies appeared as a separately published pamphlet, under the title "Untersuchungen zur physiologischen Morphologie der Thiere," which would not lead one to suspect that it contained matter of importance on the stimulation of actinians by their food.

Nagel's observations were made on a number of actinians, especially on representatives of the genera Adamsia and Anemonia, and led to the conclusion that the only part of the actinian capable of being stimulated by the soluble constituents of the food was the tentacles. This result was abundantly confirmed by Nagel's ('94[b], pp. 528 and 531) later observations, in which he showed that even when a piece of meat was placed upon the lips of an actinian, no response followed, and he believed that the animal might even die of hunger with the food at its mouth, provided the juices from this food did not reach and stimulate its tentacles.

Thus Nagel believed that the tentacles were the only part of the body capable of being stimulated by food, whereas Loeb concluded that, in addition to the tentacles, other parts of the body could thus be stimulated.

Another difference exists between the views of these two investigators. Nagel ('94[b], p. 539), in his description of the way in which the food is transported to the mouth and swallowed, mentions only muscular action. Loeb ('95, p. 419), on the other hand, believes that, in addition to the muscles, the ciliated surfaces play an important part in moving the food.

To what extent these different opinions are supported by the conditions in Metridium will be seen from the following account.

Gross Anatomy of Metridium. — In the common actinian of our coast, Metridium marginatum Milne-Edwards, the aboral disk is broadly expanded and is more or less permanently attached to some fixed object in the water. The considerable column which rises from the aboral disk may in a large, fully expanded animal reach the height of several inches. The column ends above in a complicated oral disk, which con-

sists of three zones: the tentacular zone, a broad, undulated peripheral band bearing the numerous tentacles characteristic of this species; the intermediate zone, marked by the absence of special structures and extending from the inner boundary of the tentacular zone to the outer boundary of the lip zone; and, finally, the lip zone, occupied by the swollen lips, which surround the elongated mouth, at either end of which a siphonoglyphe is usually present.

Aboral Disk and Column. — The aboral disk and column of Metridium have several peculiarities in common. By means of carmine, or other finely powdered materials, held in suspension in sea-water, it was comparatively easy to demonstrate the absence of active cilia from the surfaces of the aboral disk and of the column. And, further, when pieces of crab meat or filtered juice from crab meat was applied to either of these surfaces, no response was ever observed. I therefore believe that the column and aboral disk of Metridium are not ciliated, and are incapable of being stimulated by the soluble constituents of the food. This latter conclusion has already been announced for other actinians by Nagel ('92, p. 336).

Oral Disk. — The oral disk, as its structure suggests, is far more complicated in its functional relations than the aboral disk and the column. In dealing with this region, it is best to consider its three zones separately, beginning with the outermost.

The Tentacular Zone. — In a quiet, fully expanded Metridium, the tentacles are directed in a radial manner away from the mouth. Occasionally one or more tentacles may contract spontaneously, but as a rule they remain quietly expanded in the positions stated. If now on such a tentacular zone a small amount of powdered carmine in sea-water be gently dropped, a momentary waving of the tentacles will usually be observed, followed by a period of quiescence, during which the carmine, matted together in threads as though by mucus, is slowly carried from the bases of the tentacles toward their tips. If the tentacles upon which the experiment is made are on the outer edge of the tentacular zone, the carmine, when it arrives at their tips, will fall off beyond the oral disk. If, on the other hand, the tentacles in question do not reach the edge of the disk, the carmine will fall from their tips upon other tentacles, which in turn will transport it still farther toward the outer edge, till eventually it is carried beyond the disk. The carmine, then, must sooner or later find its way over the edge of the oral disk.

The first movement noticed on applying the carmine, the swaying movement of the tentacles, is due to muscular action, and is called forth

without doubt by the mechanical stimulation that the particles of carmine produce in coming in contact with the tentacles. At least, similar movements can be induced by gently touching the tentacles with a delicate glass rod.

The second movement, the slow gliding of the carmine from the bases of the tentacles toward their tips, is produced by the cilia that cover the tentacles. These cilia, so far as I know, are in continuous vibration, producing currents that run from the base of the tentacle to its tip. The effect of their vibration can be easily observed on a tentacle cut from a living animal. Such a tentacle has a strong resemblance to an independent organism, and by means of its cilia glides slowly through the water *with its base forward*, a fact in accordance with the observation that on attached tentacles the current produced by the cilia moves from base to tip.

It will be seen from these observations that, when carmine is put on the tentacles of Metridium, two sets of movements are observable: first, a slight momentary muscular movement, due in all probability to the mechanical stimulation of the tentacle; and, secondly, a continuous ciliary movement, by which the carmine is carried to the tip of the tentacle and dropped off, but which, so far as I am aware, is neither induced nor retarded by the presence of the carmine.

Another substance that produces a very marked effect upon the tentacles of Metridium is crab meat. If a small piece of the muscle of a crab be dropped on the tentacular zone of a quiescent actinian, the tentacles with which the meat comes in contact are thrown into active muscular movements, contracting on the sides next the meat so that eventually they come to envelop it. The tentacles thus stimulated finally take up a position with their tips pointed toward the centrally located mouth, instead of away from this opening, as in the experiment with carmine. As the cilia on these tentacles continue to wave in the usual direction, i. e. toward the tips of the tentacles, the particle of meat is moved toward the mouth and finally deposited on the lips, after which the tentacles slowly return to their original positions.

It is clear from the preceding account that the response of the tentacles, when stimulated by crab meat, does not include an alteration in the action of the cilia, but merely a temporary reversal in the direction in which the tentacle usually points, a change of a purely muscular nature. This change might be regarded either as a response to a mechanical stimulation produced by the contact of the food with the tentacles, or as the result of a chemical stimulation of the tentacles by

the soluble constituents of the food. That the latter is the true explanation is shown by the fact that, when filtered meat juice is gently discharged over the tentacles of Metridium, they respond in precisely the same way as though they were in contact with solid food, a reaction which does not follow a similar discharge of sea-water. Moreover, isolated tentacles can be thrown into active contractions if, while gliding through the water, a drop of meat juice be discharged over them.

These facts confirm Nagel's ('92, p. 335) conclusion that the soluble constituents of the food stimulate the tentacles of actinians. So far as these relations are concerned, Nagel distinguishes three classes of substances: first, materials, like sea-water, to which the tentacles are indifferent; secondly, substances, like meat, to which the tentacles attach themselves; and, thirdly, reagents, like quinine, from which the tentacles retract as from a harmful substance. So far as Metridium is concerned, I have been able to distinguish only two of these classes, namely the first and second. To the second class belong meats and meat juices, and probably all the forms of food taken by the animal; the application of this material to the tentacles produces a temporary reversal of them, so that these organs point toward the mouth instead of away from it. To the first class belong such substances as powdered carmine in sea-water. Toward such materials the tentacles seem to be indifferent; thus, if carmine be placed upon quiescent tentacles, it will be discharged over the edges of the oral disk without disturbance. If, during such an operation, a piece of meat be put on the tentacles, the latter will respond as usual, and more or less carmine together with the piece of meat will be carried into the mouth. If a piece of meat be placed on the tentacles and well started toward the mouth, a quantity of carmine will not reverse the action, for the carmine with the meat will be carried into the mouth. Thus the tentacles are indifferent to the carmine and respond to the meat only.

To the same class as carmine belong India ink, sand, small pieces of rubber, pellets of filter paper softened in salt water, etc. Nagel ('92, p. 335) states that the tentacles of Adamsia respond to sugar in the same way as to weak meat juice. In Metridium I have never succeeded in getting any response from the tentacles to either sugar dissolved in sea-water or sugar crystals; nor have I ever noticed any retraction of the tentacles when bathed with a strong solution of quinine or with a weak solution of picric acid, or when brought in contact with pellets of paper containing quinine. To all of these substances the tentacles were as indifferent as to carmine in water.

The reaction of the tentacles of Metridium to the soluble parts of the food is due in all probability to local stimulation, no tentacle moving until the soluble parts of the food have come in contact with it. This opinion is supported by what can be observed on tentacles which have been removed from the actinian, but which have been kept in such positions that their original orientation in reference to the animal can still be recognized. Such tentacles, when stimulated by meat juice, turn in a direction that indicates the original position of the mouth in reference to the given tentacle. We are therefore forced to admit that each tentacle has within itself a complete and independent nervous and muscular mechanism capable of carrying out normal responses.

The Intermediate Zone, occupying the space between the tentacles and the lips, possesses no specially differentiated structures.

When small particles of carmine are placed upon it, they remain stationary for some time, and then move slowly over the surface to the base of the tentacles, whence they are discharged from the disk, as already described. Pieces of crab meat are acted upon in much the same way, except that, when this material reaches the tentacles, these organs respond in their characteristic way, and transport the meat to the lips. That both carmine and small pieces of meat may remain motionless for some time on the intermediate zone indicates that this zone is not ciliated, a conclusion supported by the fact that, when a portion of the zone of a living animal is examined under the microscope, no evidence of ciliary currents can be detected. The movements towards the base of the tentacles, which as a rule are finally shown by the carmine and pieces of meat, seem to be due to suction produced by the tentacular cilia, or to the entanglement of the carmine or meat in extensive shreds of mucus which are being drawn by the tentacular cilia over the intermediate zone. Although nearly all the evidence favors the idea that the intermediate zone is not ciliated, the rapidity with which particles are sometimes swept over it leads one to suspect that it may possess here and there patches of cilia. If there are any cilia on this zone, they must wave away from the lips and toward the tentacles, for in this region movements in other directions have never been observed.

The intermediate zone is probably incapable of being stimulated chemically by food, etc., for, when meat juice, solutions of quinine, of picric acid, or of sugar are applied to it, no responses are given.

The Lip Zone, the innermost of the three zones of the oral disk, is in several respects more complex than the other regions described. In typical specimens it consists of two swollen furrowed lips, one on either

side of the elongated mouth, and two very pronounced grooves, the siphonoglyphes, one at either end of the mouth. Not unfrequently, as McMurrich ('91, p. 131) has already observed, only one siphonoglyphe is present; occasionally three can be observed, in which case the mouth is more or less triangular in outline, instead of forming a slit with approximately parallel sides.

As is well known, each siphonoglyphe is an open ciliated groove, by which a current of water passes into the gastrovascular cavity of the actinian. I was unable to check or reverse this current so long as the animal remained expanded, and any small body caught in it was certain to be carried inward. The animals upon which I experimented took in through their siphonoglyphes, with apparent indifference, carmine, India ink, particles of India-rubber, sand, sugar crystals, small pieces of meat, paper pellets, meat juice, solutions of quinine, sugar, and even picric acid; in the latter case to such an extent as to kill the ciliated cells lining the siphonoglyphe, and thus stop the current. It is possible that some muscular movements of the gullet, seen when the siphonoglyphes contained meat or meat juice and not observed at other times, may have been due to a chemical stimulation of the siphonoglyphe surfaces; but, as I was unable to control the meat juice so as to be sure that none of it reached the lips by diffusion, I am not certain whether this response may not have been the result of accidental stimulation of the lips.

As can be demonstrated by the use of carmine, the whole surface of the furrowed swollen lip is ciliated. When the lips are gently flooded with carmine, this substance is swept outward, and, after passing slowly over the intermediate zone, is discharged from the oral disk by the tentacles. The movement is uniform over the whole surface of the lips, and is as characteristic of the ridges as of the grooves between them. This outward current seems to be the usual one for the lips, and must be regarded as the complement of the inward current in the siphonoglyphes.

When, however, a piece of meat is placed on the lips, instead of being swept outward as the carmine was, it is carried inward and passes down the gullet, in part by peristaltic movements and in part by ciliary action. These reactions are due to the chemical stimulation of the lips and gullet by the soluble constituents of the meat, and are not the result of mechanical stimulation, as can be demonstrated by applying filtered meat juice to the lips, in which case the whole reaction follows, though no solid material is swallowed.

The peristaltic movements of the gullet are plainly muscular responses

to a chemical stimulation of the lips or gullet, or both. The inward gliding of the piece of meat over the lips is due to ciliary action, but, as the cilia of the lips usually wave outward, this movement can be explained only by assuming that the cilia have reversed their stroke. For a metazoan this certainly is very exceptional, and I was at first very much inclined to doubt the truth of this explanation, but my doubts were entirely put aside by the following observation. When a portion of the lip of a living Metridium is cut out and examined under a microscope, the cilia can be seen to wave, as indicated by the many small foreign particles suspended in the fluid about them, in a direction away from the side that was next the mouth. If now a quantity of dilute meat juice be run in under the cover-glass of such a preparation, the moment the juice comes in contact with the cilia they can be seen to reverse their movement and wave in the opposite direction. The reversal of the cilia is, then, an observed fact.

The usual stroke of the cilia of the lips, as I have already implied, is in a direction away from the mouth; for, when carmine is dropped upon the lips, this glides immediately *outward*. Moreover, in excised pieces of the lips examined in pure sea-water under a microscope, the same outward movement is obvious. Further, when a small piece of meat is dropped on the lips, it does not pass at once inward, but moves momentarily *outward*, and is then reversed and glides into the mouth. These observations show, I believe, that the cilia of the lips usually wave away from the mouth, and reverse their action only in the presence of food or similar substances.

The extent of the area over which the reversal of the cilia takes place can be easily demonstrated. If a quantity of carmine be discharged over the lips of a Metridium, the cilia by their usual action will begin sweeping the particles outward. If during this operation a piece of meat be dropped on the lips, it will be seen that, though the cilia immediately around the piece of meat reverse their movement, those in front, behind, and at either side of it continue to wave outward, the area of reversal growing in front and dying out behind as the particle of meat glides toward the mouth. In no case was the reversal of the cilia on the area of the stimulated lip accompanied by a reversal on other parts of the same lip or on the opposite lip. Repeated observations of this kind prove that the reversal of the cilia is due to direct local stimulation, and lasts only as long as the stimulating body is present. There is nothing to favor the view that the ciliary action, even though subject to reversal, is under any form of nervous control.

As in the case of the tentacles, I could distinguish for the lips only two classes of substances: materials to which the lips were indifferent, such as carmine, India ink, paper pellets, sand, sugar, quinine, and picric acid; and materials that called forth muscular responses and ciliary reversals, such as meat and meat juice, and possibly India-rubber. When a small piece of white India-rubber, such as is used in making white rubber tubing, was put upon the lips of a Metridium, it usually caused a reversal of the ciliary action, and was swept into the mouth; sometimes, after moving inward, it would turn and pass outward to be discharged finally from the oral disk by the tentacles.

It is obvious from the foregoing account that not only the tentacle, but also the lips of Metridium are capable of being stimulated by the soluble constituents of food. This conclusion is at variance with that held by Nagel, namely, that the tentacles are the only parts of an actinian capable of being thus stimulated, but coincides with Loeb's belief that other organs than the tentacles can be stimulated by the soluble parts of the food. The discrepancy between my own conclusions and those of Nagel might be attributed to the fact that we worked upon different genera of actinians; but I am not inclined to accept this explanation, for Loeb, who studied many of the same forms that Nagel did (Actinia, Adamsia, Anemonia, etc.), obtained results with which mine agree. I therefore believe Nagel to have been mistaken in his general conclusion. Further, my results show that, as Loeb has intimated, the appropriation of food by an actinian is an act partly muscular and partly ciliary, and not purely muscular, as described by Nagel.

Correlation of Movements. — Of the two kinds of responses in connection with the taking of food in Metridium, the ciliary and the muscular, only the latter shows evidence of nervous control, and I now turn to this for further consideration. As already pointed out, this response appears in connection with the stimulation of the tentacles or lips by means of the soluble constituents of the food. Stimulation of the tentacles is followed by movement of the tentacles, peristaltic movements of the gullet, and, if the stimulation be excessive, by a contraction of the sphincter of the oral disk. I have already pointed out the marked autonomy of a single tentacle. Although the tentacles are centres from which nervous impulses may proceed to the gullet and the sphincter of the oral disk, I have been unable to convince myself that one tentacle could influence another through nervous connections; I have never observed a response that could not be explained on the assumption of a direct stimulation of the tentacles.

Stimulation of the lips induces a peristaltic movement of the gullet, and, if excessive, a contraction of the sphincter of the oral disk, but is never, so far as my experience extends, accompanied by a movement of the tentacles. These were the principal correlations observed in the muscular responses to stimulation by food.

The looseness of the nervous organization in Metridium is well illustrated by experiments that were made first by Nagel ('92, pp. 336 and 337), and that I have attempted to carry out in the following way. Choosing a definite region in what, for convenience, we may call the right side of the tentacular zone of Metridium, I placed upon it a small piece of meat and recorded the time it took for this to be swallowed. I next placed on the same region a piece of bibulous paper soaked with dilute meat juice and again noted the time required for the animal to swallow this object. These operations were repeated in regular alternation with the results that are shown in the first column (Aug. 24, R. Side) of the following table. The inspection of this column shows that the time required to swallow a piece of meat varied from 40 to 85 seconds, and that the variations in these periods form no regular series. The periods occupied in swallowing the paper soaked in weak meat juice form a series of intervals of increasing lengths till finally at the eighth trial the paper was not swallowed at all, the same being true of all subsequent trials. In other words, the successive application of a very weak stimulus is accompanied, not by the summation of the effects of stimulation, but by a gradual decline in these effects, till finally the response fails entirely.

After having produced this effect upon the right lip, I repeated the experiment upon the left, with the view of determining whether the condition brought about in the right lip had spread to the left one. As the second column (August 24, L. Side) in the table shows, there was no evidence of such a result; in fact, it took longer for the left side to become indifferent to the stimulus than it had taken for the right, instead of the reverse, as one might have expected.

This double experiment was repeated on the same animal on August 25, 26, and 27. As it was necessary to make up a new solution of meat juice each day, and as it was impossible to be certain that the strength was the same each time, the records for different days have no great value for comparison. I therefore give only the record for the last day, which is essentially similar to the intervening ones, and illustrates, even better than that of the first day, the extreme looseness, or even independence, of the nervous activities of the two sides of the animal. This may

be taken as a proof of the lack of physiological centralization in the nervous functions of these low organisms, a condition that corresponds with the diffuse state of their nervous systems.

		August 24, 1895.		August 27, 1895.	
		R. Side.	L. Side.	R. Side.	L. Side.
1	Meat	85 sec.	45 sec.	40 sec.	55 sec.
2	Paper	80 "	90 "	60 "	70 "
3	Meat	50 "	45 "	50 "	35 "
4	Paper	90 "	∞	55 "	45 "
5	Meat	40 "	45 "	30 "	45 "
6	Paper	105 "	55 "	75 "	65 "
7	Meat	50 "	35 "	35 "	40 "
8	Paper	∞	105 "	60 "	55 "
9	Meat	70 "	35 "	20 "	35 "
10	Paper	∞	85 "	55 "	95 "
11	Meat	40 "	30 "	45 "	30 "
12	Paper	∞	95 "	63 "	145 "
13	Meat		35 "	30 "	45 "
14	Paper		∞	∞	∞
15	Meat		35 "	40 "	30 "
16	Paper		∞	65 "	90 "
17	Meat			35 "	45 "
18	Paper			∞	∞
19	Meat			35 "	30 "
20	Paper			∞	∞

Summary. — The outer surfaces of the column and aboral disk of Metridium marginatum are not ciliated, and are incapable of being stimulated by the soluble constituents of the food.

The tentacles are covered with cilia that wave always from the base of these organs towards their tips. The action of these cilia was not noticeably influenced by the soluble constituents of the food.

The tentacles normally rest with their tips pointed away from the mouth. When stimulated with meat juice, they point temporarily toward the mouth (muscular response). Many other substances, sugar, quinine, etc., fail to stimulate them.

The intermediate zone of the oral disk is probably devoid of cilia, or possesses at most only a few patches ; these, if present, wave away from the mouth. This region cannot be stimulated by the soluble parts of the food.

The cilia of the siphonoglyphes wave invariably inward. Possibly the stimulation of the siphonoglyphe surfaces by meat juice gives rise to a peristaltic movement in the gullet.

The cilia of the lips usually wave outward. The direction of their stroke can be temporarily reversed by meat juice. Application of this to the lips calls forth peristaltic movements of the gullet.

The contraction of the sphincter of the oral disk and the peristaltic movements of the gullet can be produced by stimulating with meat juice either the lips or the tentacles. To induce movements in the tentacles, meat juice must be applied directly to them.

The effects of frequently repeated weak chemical stimuli on one side of the oral disk are not transmitted in any appreciable degree to the other side, i. e. the nervous functions are not centralized.

In an expanded quiescent Metridium, the tentacles point away from the mouth and their cilia wave towards their tips; the cilia in the siphonoglyphe wave inward, those on the lips outward. If any indifferent substance is dropped on these parts, it is carried along with the ciliary currents. If a piece of meat be placed on the tentacles, these turn their tips toward the mouth (muscular response), and their cilia carry the meat to their free ends, from which it drops on the lips. The cilia of the lips thereupon reverse, and the meat passes down the gullet, partly by ciliary action and partly by peristaltic movements (muscular response).

CAMBRIDGE, January 6, 1896.

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THE ANATOMY AND HISTOLOGY OF CAUDINA ARENATA GOULD.

BY JOHN HIRAM GEROULD.

WITH EIGHT PLATES.

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No. 3.—*The Anatomy and Histology of Caudina arenata Gould.*[1]

By John Hiram Gerould.

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[1]Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy at Harvard College, under the direction of E. L. Mark, No. LVI.

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1. INTRODUCTION.

Our knowledge of the Molpadiidae has hitherto been much less complete than that of the Synaptidae, Holothuriidae, and Cucumariidae, chiefly on account of the difficulty in obtaining an amount of material sufficient for a thorough study of any one form. It is true, that the researches of Semper ('68), Kingsley ('81), Danielssen and Koren ('82), Ludwig ('91[a]), and others have in some measure acquainted us with the anatomical structure of this group, and that the investigations of Teuscher ('76) and Jourdan ('83) have thrown some light upon the histology of these forms; but it has seemed desirable to attempt with a sufficient amount of material at hand a somewhat more thorough investigation into both the anatomy and histology of the group. Hence I undertook, at the suggestion of my instructor, Dr. E. L. Mark, the study of Caudina arenata, specimens of which can sometimes be found in large numbers upon the sandy beaches near Boston, during or immediately after severe storms that are attended by easterly winds.

During a residence of three years in Cambridge, I have visited Crescent Beach, Revere, Mass., whenever it seemed to be at all probable that specimens of Caudina could be obtained. Often I have returned empty-handed, but at other times it has been possible in a single excursion to secure from one to fifty, or even more, individuals. My endeavors to obtain embryological material have thus far been fruitless. Although in both sexes the sexual elements appear to be mature during the early spring, and male individuals in aquaria have at that time been observed in the act of emitting sperm (see p. 179), I have succeeded neither in obtaining ova that had been thrown out into the water, nor in finding either segmented or fertilized eggs within the female, nor in artificially fertilizing the eggs.

I gladly take this opportunity to express a deep-felt gratitude to Dr. Mark for the invaluable assistance which he has rendered me during the prosecution of these studies. I would likewise make grateful acknowledgment of the kindness of Mr. Alexander Agassiz in permitting me to make use of the specimens of Holothuroidea collected in the expedition of the U. S. Steamer "Blake." I am also much indebted to J. S. Morris, M. D., of Revere, Mass., for valuable aid which he has given me in collecting material for study.

Regarding *methods*, I would first call attention to the use of magnesium sulphate as a stupefying reagent. It was first recommended, I believe, by Tullberg ('91), and its action has recently been more fully described by Redenbaugh ('95). The use of a stupefying reagent in the preservation of holothurians in an expanded condition being imperative, I have given this salt a thorough trial, and have found it entirely satisfactory for the purpose. The method which I have employed is as follows: A specimen of Caudina is first allowed to become well expanded in a small quantity of sea-water, and then crystals of magnesium sulphate are added, a small teaspoonful at a time. If contraction occurs, the salt is added more slowly or the use of it is suspended entirely until the animal again expands.

Perenyi's fluid gave better general results in killing than any of the other reagents which were employed. Corrosive sublimate was found to be the most satisfactory in the preservation of the ovaries. Previous to embedding an object in paraffine, it was often found necessary to remove bubbles of carbon di-oxide, which had gathered in the tissues during decalcification. This was accomplished, as suggested by Cuénot ('91), by placing the specimen under the receiver of an air-pump and exhausting the air. For staining on the slide nothing was found to surpass Ehrlich's haematoxylin followed by eosin. Biondi's triple stain — acid fuchsin, methyl green, and orange — was used with excellent success in studying the development of the zona radiata and other phenomena in oögenesis. For demonstrating outlines of epithelial cells a one per cent solution of silver nitrate was successfully employed, after washing the fresh tissue thoroughly with distilled water.

It may be of interest to add that I have given the rapid method of Golgi what I believe to be a thorough trial, but without the slightest success. For weeks at a time I have experimented with it, treating tentacles and other parts of the body according to the well-known

rapid method. The silver appeared to have not the slightest affinity for the nervous elements.

Solutions of methylen blue were at various times injected into the body-cavities of stupefied individuals of both Caudina and Synapta, and the specimens allowed to lie in sea-water for a longer or a shorter time. Thus far this method has likewise been of no avail. These two methods, so fruitful when applied to other invertebrates and to vertebrates, deserve a more extended trial with echinoderm tissue than has been given them, for the Golgi method may capriciously fail when employed in the study of one animal, although it affords excellent results when applied to a closely related form.

2. EXTERNAL FEATURES.

The total length of a full-grown and well-expanded specimen of Caudina arenata is 160–170 mm. The whole body may for convenience be regarded as consisting of two parts, the trunk, or body proper, and the tail. The trunk is spindle-shaped, tapering rapidly in front toward the base of the tentacles and posteriorly with about the same rate of curvature toward the tail (Plate **4**, fig. 46). The length of the trunk in a specimen 170 mm. long is about 110 mm., with a maximum diameter of about 20 mm., whereas the tail measures about 60 mm. in length, or in general about 35 per cent of the total length of the animal. The tail is differentiated from the body proper only by the fact that the rate of curvature of its surface from before backwards is decidedly less than that of the posterior part of the trunk. Its diameter immediately behind the trunk region is 9–10 mm.; from this point backward it gradually diminishes in thickness and terminates in a truncated tip 3 mm. in diameter. Kingsley's comparison of the shape of Caudina to that of an elongated pear is apt when applied to alcoholic specimens preserved without previous stupefaction, but not when applied to the living animal.

The integument is translucent and destitute of pigment; the color, which depends upon the state of aeration of the blood, varies from pink to a purplish hue; in alcoholic specimens it varies from a milky white to pale brown.

Around the mouth are grouped in a single row fifteen tentacles, all of equal size (Plate **1**, fig. 4). Each consists of a short, nearly

cylindrical, but slightly tapering basal portion about three millimeters in length, bearing upon its free extremity four conical or finger-like lobes or processes, each about one millimeter long. The latter are arranged in pairs; the two which arise on the side next the mouth may be called the axial pair; the others, situated upon the outer side of the extremity of the tentacle, we may designate as abaxial. The axial processes are slightly larger than the others, especially in the diameter of the base, and usually stretch forward, but with their apices turned away from each other; the more slender abaxial processes are frequently much curved outward and backward. These four lobes of the tentacles spread further in the radial than in a tangential direction. Pigment spots are not present on the tentacles of Caudina, though they have been described in connection with the closely related form, Haplodactyla.

The statements made in regard to the number of tentacles in Caudina have been various. Gould ('41) found eleven; Ayres ('52) and Selenka ('67) twelve; while Kingsley ('81) was of the opinion that the number varies from twelve to fifteen, as he found the latter number in counting the tentacles of several individuals. Pourtalès ('51) had observed the number to be fifteen, each being, as he thought, divided into *five* lobes; and Marenzeller ('82) upon examining numerous specimens found always fifteen tentacles, each having four lobes. Although I have counted the tentacles of scores of specimens, I have never found an individual with any other number than fifteen. Doubtless the contracted condition of the specimens examined by the earlier investigators led them to overlook some of the tentacles.

A prominent cone-shaped genital papilla is situated in the dorsal interradius 3 or 4 mm. behind the ring of tentacles. It was not to be found in the youngest individuals that I examined, which measured about 40 mm. in length. In the adult it is approximately 2 mm. in length, and appears to be slightly larger in the male than in the female.

There are five conical, transparent, anal papillae, one at the terminus of each radius. They are so minute as to be scarcely discernible without a lens, even in the living and expanded animal; they are about 0.2 mm. long. When the anus is open, these papillae lie stretched out, pointing directly backward; when the sphincter muscle contracts to close the anus, the papillae

become somewhat contracted and bent inward, so that they lie against a circumanal region, pentagonal in shape and without spicules. All previous observers have, I believe, overlooked these papillae.

3. HABITAT, HABITS, FOOD, ETC.

Caudina arenata lives buried in the sand where the water is at least a few feet deep at low tide. Though I have repeatedly tried to obtain specimens by digging at the water's edge at the lowest spring tides, I have never succeeded in finding any in this way. During an easterly gale, if it be of sufficiently long duration, numerous specimens are likely to be dislodged from the sand and cast upon the beach.

The variety of C. arenata described by Théel as var. armata was found to occur at depths of 898 fathoms and 1242 fathoms; in the former case at Lat. 35° 44′ 40″ N., Long. 74° 40′ 20″ W. (1880), and in the latter instance at Lat. 41° 24′ 45″ N., Long. 65° 35′ 30″ W.

Caudina burrows head foremost mainly by means of its tentacles, which by the alternate contraction of their outer and inner longitudinal muscles move back and forth in a radial direction, crowding aside the grains of sand which lie in its course. A forward movement is facilitated by the animal swallowing the sand immediately in front of it, as is said to be the case also with Synapta and many worms. The dark-colored organic matter contained in the sand, which is swallowed in great quantities, forms the principal food of the animal.

As observed in an aquarium containing well-aerated sea-water and provided with an abundance of sand, so that the environment is as nearly as possible normal, Caudina lies for days at a time entirely buried in the sand, save the tip of the tail. The exposure of the tail permits the respiratory trees to perform continually their function; through the anus, water is forced out of the respiratory trees and drawn into them by the alternate contraction and relaxation of these organs and of the wall of the body. The latter, by reason of its natural rigidity, resumes its normal shape when its circular muscles are relaxed, and so increases the capacity of the body-cavity, thus bringing about an influx of water. These movements are accompanied by the correlated opening and closing of the anus by

means of the alternate activity of the sphincter and the opposing radial muscles. The act of opening or of closing the anus during the respiratory process requires only about a second; the anus is gen erally kept open 18–20 seconds and then closed for 13–17 seconds. A definite period of dilation often alternates with another definite period of closure; there may be some irregularity in the length of the recurring periods, but in any event, the period of dilation slightly exceeds the period of closure.

Caudina, when placed in a jar of sea-water in which no sand has been provided, lies upon one side of the body in a curled posture, the longitudinal muscles of the dorsal bivium being much contracted, those of the ventral trivium, relaxed; the buccal surface is turned downward, and the tail passes either over the head region or close to it in front. When cast upon the beach by the surf, Caudina assumes a position similar to that just described, and begins to burrow slowly into the sand; two or three hours may elapse before all of it except the tip of the tail has disappeared below the surface.

4. ANATOMY AND HISTOLOGY OF THE BODY-WALL.

The body-wall in Caudina, as in all holothurians, consists of four layers; these in passing from without inward are (1) an epithelium of columnar cells, (2) a thick layer of connective tissue, enclosing calcareous bodies and underlaid in the anterior part of the body by a layer of nerve fibers running parallel to the surface of the body, (3) a muscle layer, made up of five interradial areas of circular fibers that are interrupted at each radius and of five paired radial bands of longitudinal fibers, and finally (4) a thin epithelium of flattened, ciliated cells next to the body-cavity.

1. EXTERNAL EPITHELIUM.

Cuticula. The thin structureless cuticula (*cta.*), which covers the entire surface of the body and lines the pharynx and cloaca, presents in Caudina no peculiarities which distinguish it from that in other holothurians.

The *epidermis* (*e'th.*) is composed of a single layer of columnar cells, which in the anterior part of the body (Plate **1**, fig. 2) are about

20 μ in length, 4–5 μ in thickness, with nearly spherical nuclei 4 or 5 μ in diameter. Their deep ends are tapering, so that the layer merges into the underlying connective tissue without causing any sharply defined line of separation to appear in sections. In the middle and posterior parts of the body the height of these cells is less than in the anterior part.

Among the ordinary epithelial or supporting cells just described are slender sensory cells, the deep ends of which are undoubtedly in connection with a subepithelial nerve plexus consisting of numerous large, stellate, ganglion cells (*cl. gn.*), each of which gives off several fibers. Bundles of nerve fibers pass from this nerve plexus through the connective-tissue layer to the layer of nervous tissue which immediately underlies it.

The *epidermis of the tentacles* is thicker than that of the rest of the body-wall. It consists of ordinary supporting cells (*cl. sst.*), nerve cells, and numerous gland cells, which are similar to the *tubular* gland cells which Hamann has found in Synapta. The supporting cells (Plate **2**, figs. 6, 7, 8, 15) do not differ from those of the body-wall, except in the unusual length of those found on the four tentacular processes. Here they may attain a length of 50 μ.

The nerve cells (Figs. 9 and 15, *cl. sns.*) are similar to those in Synapta described by Hamann. The nucleus lies between the middle part and the superficial extremity of the slender cell. The peripheral end tapers to a fine point, and the deeper part is prolonged into a slender fiber.

The tubular gland cells (Figs. 10 and 15, *gl. tbl.*) are 48–50 μ in length with a nucleus, about 4×5 μ in dimensions, situated near the middle of the cell. The peripheral part of the cell is tubular or ovoid, and between this part and the nucleus a constriction can be seen in most cases. The nucleus occupies a swollen portion of the cell, the deep end of which tapers rapidly from the region of the nucleus. The granular contents of the peripheral part of the gland cell stain deeply with haematoxylin, and thus these cells are sharply differentiated from other parts of the epithelium. Whereas gland cells are found in small numbers over the whole anterior part of the body including the buccal region, in the tentacles, especially upon the finger-like lobes, they are exceedingly numerous. I have never found them in groups connected with a nerve bundle, such as Hamann describes in Synapta, although the groups of sensory cells in Caudina, presently to be described, occasionally contain a gland cell.

The cylindrical or conical bundles of cells which are found upon the oral side of the axial pair of tentacular processes (Plate **2**, fig. 16) consist mostly of sensory cells; each bundle is connected with a strand of nerve fibers which arises from the tentacular nerve and among which are interspersed ganglion cells. These groups of cells resemble in some respects the sensory buds upon the tentacles of Synapta, but the epithelium surrounding the group of nerve cells in Caudina is not modified to form a protecting envelope, nor have I found a ciliated depression upon the surface of the group such as Hamann has described in Synapta. I regard these groups of cells as a simple form of sensory bud.

2. CONNECTIVE-TISSUE LAYER.

The layer of connective tissue is thinnest in the anterior part of the body; immediately behind the tentacles it measures only 170 μ in thickness, whereas only a short distance posterior to this, viz., opposite the posterior extremity of the radial calcareous plates, it is 290 μ thick. In the middle of the body it may attain a thickness of 350–430 μ, while in the tail region it is slightly thinner.

As in other holothurians, it is composed of a transparent homogeneous matrix in which lie numerous fibers, among which are interspersed bipolar or stellate cells, the longest diameter of which in sections may be 15–16 μ; each of these encloses an oval nucleus of perhaps 3×7 μ (Plate **1**, fig. 2). Fibers arise from the cells just mentioned; the superabundance of fibers and scarcity of cells lead one to think it improbable that in Caudina the fibers are all prolongations of cells, though it is the opinion of Hamann that such is the case in certain holothurians.

In the superficial portion of the layer of connective tissue (Fig. 2) immediately beneath the epithelium are located the calcareous bodies. This is the *couche aréolare* of Jourdan and Hérouard. The connective-tissue fibers which entwine themselves around the calcareous bodies run in all directions, but in the thick deeper portion of the connective-tissue layer they run in general parallel to the surface of the body.

In the connective-tissue layer and among the external epithelial cells are frequently found wandering cells (Plate **1**, fig. 2, *cp. sph.*), called by Durham ('92) spheruliferous corpuscles, the *Plasma-*

wanderzellen of Hamann, and the *amibocytes mûriformes* of Cuénot. They consist, as is usual, of a mass of highly refractive spherules — which stain readily with eosin, but do not take carmine — imbedded in a small amount of hyaline protoplasm, which encloses a spherical nucleus; this is about 2.6 μ in diameter. These cells, which, like other amoeboid cells, assume various shapes, measure about 8 × 9.3 μ when they take on a spherical form.

Parallel muscle fibers arranged into the form of hollow cylinders (*tbl. mu.*), which recur at short, irregular intervals, run outward from points in the transverse musculature, through the connective-tissue layer and terminate between the calcareous bodies immediately beneath the epithelium (Plate **1**, fig 5). Each *muscle cylinder* in a relaxed condition runs sinuously and without branching from its point of origin to its terminus among the calcareous bodies. At their peripheral extremities the fibers of the cylinder generally approach one another, come into contact, and form a narrow rounded point, to which are attached diverging fibers of connective tissue. The core of the cylinder appears to consist of the homogeneous matrix of the connective-tissue layer.

The striking resemblance of these muscular tubules to vessels which in the Holothuria pedata connect the ambulacra with the radial canal led Semper ('68) to the erroneous conclusion that they are actually in connection with the radial canal. From a study of extensive pieces of the body-wall of young individuals, stained, cleared, and mounted in balsam, as well as of sections, I have found that the muscular tubules are directly continuous with the transverse muscles of the body-wall (Plate **1**, fig. 5), and I have not in a single instance found them connected with the radial canal. The only vessels leading out of the radial canals that I have succeeded in finding are in each canal the three which run to the tentacles and the three at the tip of the tail. The latter, which are to be described in the account of the water-vascular system, are undoubtedly rudimentary ambulacral vessels.

The structure of the muscular tubules suggests that they also may be considered to be rudimentary ambulacral vessels, the central ends of which have lost their primitive connection with the radial canal and have secondarily become united to the transverse muscles of the body-wall. On the other hand, they may never have had any connection with the radial canal, having arisen directly from

the transverse musculature, fibers of which may have grown out through the connective tissue of the integument and sooner or later acquired the arrangement suggestive of that of the muscle fibers of the ambulacral vessels. I cannot imagine, however, in that case what could have been the cause of the arrangement of the fibers into a hollow cylinder. The uniformity in the occurrence of this arrangement into cylinders inclines me, therefore, in the absence of any embryological evidence, toward the former view.

Whatever may be the morphological significance of these muscular cylinders, their present function seems to be to support the transverse muscles by providing for them an insertion in the firm outer part of the integument which contains the calcareous bodies, and furthermore to unite firmly together the various parts of the integument.

Semper ('68, p. 46) undoubtedly had these structures in mind in describing rudimentary ambulacra in Haplodactyla molpadioides and Caudina arenata. These forms, he says, "besitzen sowohl die Radiärcanäle wie auch die von ihnen ausgehenden, quer die Haut durchsetzenden Wassergefässe, welche bei den füssigen Holothurien in die Füsschen übergehen, hier aber unter der Epidermis blind endigen." Teuscher ('76, p. 549), on the other hand, positively denies the existence in Caudina of any such lateral branches of the radial canal as Semper describes. Danielssen and Koren ('82) state that in Trochostoma Thomsonii the radial canals along their course send numerous lateral branches which end blindly in the skin, and Sluiter ('81) makes a similar statement in regard to Haplodactyla hyaloides. I have found no muscular tubules in preparations of the integument of either Trochostoma antarcticum or Ankyroderma Jeffreysii.

3. CALCAREOUS BODIES.

The calcareous bodies in the integument of Caudina (Plate **3**, figs. 17–19, 26–33) are similar in form to the stool- or table-shaped spicules of the Cucumariidae and Holothuriidae; the leg of the table always points outward, *i. e.*, away from the axis of the body.

A complete calcareous table is composed of a smooth, flat, nearly circular or oval disc, measuring in an average of twenty specimens 106.6 μ broad by 116.9 μ long. The disc of the smallest table measured was nearly circular and 91.5 μ in diameter, whereas that of the largest one was 132 μ by 135 μ in dimensions.

The disc has an undulating margin and is perforated by a central opening, having a diameter generally somewhat more than a third of that of the disc, and also by a single circular or oval row of 8–12 holes, which lie between the central opening and the margin. In addition to these there are occasionally a few smaller holes between this circular row and the margin of the disc.

The leg of the calcareous table when completely formed is 80–98 μ in height, and is made up of four rods which are perpendicular to the plane of the disc. They do not arise from the outer rim of the disc, as in C. Ransonetti (Marenzeller), but from that part which lies between the central orifice and the row of holes surrounding it. The portion of the four rods attached to the disc comprises the original X-shaped spicule (Figs. 26–28), which is considerably arched across the central perforation of the disc, the convexity extending toward the surface of the body.

Selenka ('67) described these spicules and figured one of them, but did not describe the leg of the completely formed table. Kingsley ('81) apparently overlooked entirely the leg, though he figured accurately the two concentric rings of the disc. Semper ('68) gives an accurate figure of both parts of the calcareous table.

Development of the calcareous tables. — The manner of development of these calcareous bodies from an X-shaped fundament is similar to that in all other known holothurians. If a piece of the integument of an immature specimen of Caudina, measuring perhaps 5 mm. in total length, be stretched out to its natural dimensions upon a bit of cork, stained to show the nuclei, and mounted in balsam, calcareous bodies in different stages of development (Plate **3**, figs. 26–33) are found beneath the external epithelium, covering nearly the whole surface. The smallest X-shaped spicule observed (Figs. 26, 26 a) measured 23 $\times$ 27 μ diagonally; the body of the spicule, from which the arms extend, has a long axis of about 14 μ, and a thickness of 4–5 μ. As the spicule increases in size the body does not materially change in dimensions, but the arms increase in length till they measure about 20 μ long, with a corresponding increase in thickness, when a second branching (Fig. 29) occurs. A third set of dichotomous branches is then sent off, the central ones of which unite with their fellows from the adjacent primitive branches, whereas the peripheral ones send off the branches of the fourth set which, uniting, form the rim of the disc (Figs. 32, 33).

The leg of the calcareous table is developed upon the primitive X-shaped spicule, the arms of which are curved inward toward the axis of the animal; they form the attached end of the leg. From about the middle of that side of each arm which faces the surface of the body arises a single rod, which branches dichotomously in a direction parallel to the margin of the disc (Fig. 33). These branches subsequently unite to form the basis of the free extremity of the leg.

The calcareous tables are found in the integument of all parts of the body except the buccal region, the tentacles, the anterior part of the body immediately behind the tentacles, and a small circum-anal area. They lie in a single layer in the outer part of the connective tissue of the body-wall and are so abundant that the edges of the discs of adjacent tables overlap each other slightly during muscular contractions of the body-wall.

Through the kindness of Mr. Agassiz I have had an opportunity to examine the integument of specimens of *C. arenata* var. *armata* Théel, dredged in the Blake expedition (Plate **3**, figs. 34–37). Théel ('86 b) has already given a good general description of these calcareous tables, but without figures. They are several times as large as those of C. arenata Gould, and differ from them markedly in form. The disc is smooth and commonly of a somewhat triangular shape, though it may be more or less elliptical or quadrangular; the margin is uneven, and there are between twenty and thirty perforations in each disc. The spire or leg is composed of *three* rods, as Théel has described it. These have numerous spinous processes upon them and are united to one another, as in C. arenata, near the base as well as at the extremity. The following measurements give a fair idea of the range in size and proportions of the disc: 150 μ × 270 μ, 165 μ × 260 μ, 240 μ × 260 μ, 245 μ × 265 μ. The length of the leg is about 155 μ.

The calcareous bodies of the variety armata are distributed in the integument in the same way as in the type-form. Those found in the tail region, near the anus, are similar to those found in the trunk.

4. MUSCULATURE.

The musculature of the body-wall of Caudina, like that in other holothurians, consists of (1) longitudinal muscles, radial in position, and (2) transverse muscles, interradial in position.

(1) The radial longitudinal muscles are disposed in five pairs, the members of each pair being separated from each other by the width of the radial water canal, to the wall of which they are both attached.

There are no special retractor muscles in Caudina such as exist in the genus Molpadia, but the anterior ends of the radial muscles serve to draw in the aquapharyngeal bulb. Each pair has its insertion as a single muscle in the corrugated outer surface of the anterior part of a radial calcareous plate. Toward the anterior extremities of the radial muscles the interradial edges of each of those composing a pair curve inward toward each other, until they come together. The adradial edges of both approach each other and unite immediately beneath the radial water canal, so that anteriorly there is in each radius a single longitudinal tubular muscle, which includes for a short distance a central cavity, lying deeper than the radial water canal.

In the posterior part of the body the longitudinal muscles of each pair run backward as semicylindrical trunks close to each other but not in contact, as they are, according to Ludwig, in Ankyroderma musculus. They taper gradually and are finally inserted into the connective-tissue layer of the body-wall at the tip of the so-called tail.

The supposed pair of smaller longitudinal muscles, described and figured by both Clark ('65) and Kingsley ('81) as lying more superficial than the longitudinal muscles just described, and immediately below the radial nerve, do not exist.

(2) The transverse muscles are limited to the five broad interradial areas lying between the pairs of longitudinal muscles. The fibers are inserted into the connective tissue a little to one side of each radius, and are not sufficiently numerous to form in each interradius a continuous sheet, except when the animal is shortened by the contraction of the longitudinal muscles. In the anterior part of the body, just behind the tentacles, the fibers become continuous across each radius, thus forming an uninterrupted circular muscle, which serves, after the tentacles have been retracted, to constrict the head region.

The parallel fibers composing the longitudinal muscle bands can easily be separated from one another by maceration in 20 per cent nitric acid. The fibers (Plate **2**, figs. 11, 12), are spindle-shaped tapering to a single point at either end. Each has an oval nucleus

of 10–15 μ by perhaps 5 μ, situated midway between the ends of the fiber, but a little to one side of its axis. Each nucleus is surrounded by a small remnant of granular protoplasm. A single fiber under ordinary conditions of relaxation is from 0.6 to 0.7 mm. long. The cross section of a fiber has usually the shape of an irregular polygon; it is rarely circular.

The fibers are not entirely homogeneous but ordinarily show a faint longitudinal striation, which is probably due to their being composed of fibrillae.

A fine sarcolemma encloses the fiber, and when the latter is in a state of contraction this sheath is thrown into transverse folds, which sometimes resemble a delicate filament running spirally around the fiber.

5. INNER EPITHELIUM.

The epithelium lining the body-cavity consists of flat cells with polygonal outlines. They are everywhere provided with cilia.

5. NERVOUS SYSTEM.

The nervous system in the Molpadiidae has been investigated in a general way by Semper ('68), Teuscher ('76), Danielssen og Koren ('78, '79), and by Jourdan ('83); but later investigators, including Semon ('83), Hamann ('83, '84), and Hérouard ('87, '89), who have paid especial attention to the histological structure of the nervous system in holothurians, have not extended their studies to the anatomical and histological conditions of this system in the Molpadiidae.

In studying the nervous system in Caudina certain questions which apply to the whole group of Holothuroidea are naturally encountered, such as the connection and significance of the cellular elements of the central nervous system, the distribution of the nerves arising from the inner radial band, the number and interrelation of neurons extending between the peripheral sensory cells and the ganglionic cells of the central nervous system, and the existence or absence of a circular epineural canal.

1. CENTRAL NERVOUS SYSTEM.

The central nervous system in Caudina resembles that of all other holothurians in being composed of a circular band, surrounding the buccal opening, and of five equi-distant radial bands, each of which consists of an outer band, arising from the circular band and running backward in the radii to the tip of the tail, and of an inner band having the same general course.

a. Circular Nerve Band.

The nerve ring in Caudina does not lie within the calcareous ring, as is said to be the case in the Synaptidae, but anterior to it. Hence I have described this nerve band as surrounding the mouth rather than the pharynx. It is situated beneath a loose connective-tissue layer, immediately internal to the base of the tentacles (Plate **4**, fig. 44). An epineural space (*e'n. crc.*) separates it from the connective tissue in front of it. In cross section the nerve ring is somewhat elliptical (Plate **3**, fig. 42, Plate **4**, fig. 44); it is flattened in an anterior-posterior direction and to such an extent that the greater diameter may be 4–5 times the lesser one (242 μ × 56 μ), or it may be only 2–3 times as great (240 μ × 93 μ). A deep, narrow furrow runs round the nerve on the axial side of the anterior face, extending obliquely outward and backward. It is of nearly uniform depth in any one specimen, measuring 56 μ deep in sections of one individual, 72 μ in those of another. The part of the nerve ring which forms the lining of the furrow presents the same cellular conditions as the rest of the anterior part of the circular band.

The nerve ring, as in other holothurians, consists of delicate longitudinal fibrillae, which are interspersed with oval, lightly-staining nuclei of ganglionic cells. Its anterior surface is covered with somewhat smaller, deeply-staining nuclei. From these nuclei, which belong to the *Deckepithel* of Hamann, arise coarse transverse fibers, more than twice the diameter of the nervous fibrillae (Plate **3**, fig. 41). The cells which I have designated as ganglionic and which lie embedded within the nerve band consist each of a large oval nucleus, measuring on the average 4.25 μ × 6.33 μ, and a small amount of cytoplasm. From them probably arise the fibrillae which make up the principal part of the nerve band. These cells, which

are here much more numerous than in the radial bands, are frequently arranged in long lines parallel to the direction of the circular band, their nuclei being so oriented that their long axes extend in the same direction.

The nuclei of the covering epithelium (Hamann's *Deckepithel*) differ from those of the ganglionic cells in their smaller size ($4\ \mu \times 5.33\ \mu$) and in the fact that they stain more deeply. The fibers proceeding from them, which, with Hamann, I regard as non-nervous supporting structures, run through the substance of the nerve ring perpendicularly to the direction of the band and in an antero-posterior direction. The deep ends of these fibers are often swollen, as Hérouard has described them in Cucumaria; their conical tips abut against the underlying connective tissue. I have found that in Caudina the nuclei of the covering epithelium are evenly distributed, not being especially numerous in the interradii. Jourdan ('83), on the contrary, found them in the forms which he examined heaped together in the interradial parts of the nerve ring.

b. Radial Nerve Bands.

Each radial nerve consists in Caudina (Fig. 40, 43) of (1) a thick outer band,—crescentic in cross section,—which arises from the nerve ring and terminates near the posterior extremity of a radius immediately below the epithelium, in front of an anal papilla, and (2) a thin inner band, which is closely apposed to the outer band — being separated from it by only a thin connective-tissue partition — and presents along the greater part of its inner surface a median furrow. The inner band divides anteriorly into two branches, each of which subdivides, to innervate the anterior ends of the radial longitudinal and the interradial transverse muscles of the body-wall, and disappears entirely as a band immediately posterior to the junction of the outer band with the nerve ring. Posteriorly the inner band accompanies the outer band to near the end of the radius. It terminates a little in front of the posterior extremity of the outer band with a slight enlargement (Plate **4**, fig. 50). It sends nerve fibers to the circular musculature of the region and to a pair of rudimentary ambulacra lying opposite this point. Perhaps the ambulacra in question are also supplied by nerves from the outer band.

Immediately external to the radial nerve is the radial epineural canal (*e'n. r.*), which is continuous with the circular epineural canal,

already described as lying anterior to the nerve ring. Immediately beneath the inner band of the radial nerve is the pseudohaemal canal of Hamann, the *canal sous-nervien* of Hérouard, for which I propose the name *hyponeural canal* (*h'pn. r.*). The radial canal of the water-vascular system, as is well known, lies beneath the hyponeural canal. In the connective tissue of the wall between these two canals is the radial haemal lacuna (*sng. r.*).

Outer band.— The structure of the outer band, as in other holothurians, is similar to that of the nerve ring. The nuclei which are embedded within the mass of longitudinal fibrillae resemble closely those of the nerve ring. Like Hamann, I have found them most numerous in the anterior part of the nerve band. The linear arrangement of nuclei observed in the nerve ring is also noticeable here, but, from the comparative infrequency of the nuclei, less obviously.

The nuclei of the covering epithelium are distributed over the whole external surface of the outer band, but are especially abundant in two parallel columns (*Zellsäulen*), one on either side of the median line, as Semon originally found to be the case in Synapta. In sections stained successively with haematoxylin and eosin the fibers of the covering epithelium are brought out sharply, being colored with the eosin. As they are very nearly perpendicular to the length of the radial nerve or nerve ring, they can readily be followed from the nucleus through the entire thickness of the outer band to the connective-tissue partition, in which they terminate. In no case in which these fibers are thus clearly demonstrated can there be any doubt that they run across the nerve band independently of each other and without branching. My observations respecting this point differ from those of Teuscher, Semon, and Hérouard, all of whom have inclined to the view that these fibers branch. I am led to adopt the view of Hamann that they are purely supporting structures. If the nerve band is somewhat compressed in the direction of the length of these fibers, they appear exceedingly sinuous (Plate **3**, fig. 41) both in the radial nerve and in the nerve ring. This would seem to indicate, as Hérouard has suggested, that they are not perceptibly elastic.

Some of the nuclei of the covering epithelium are connected with processes which run outward across the epineural canal and terminate in the outer wall of this space. These fibers have their greatest diameter next the nucleus with which they are in

connection, and the outer extremity is often exceedingly slender, especially when the epineural space is filled with fluid and the fibers are consequently stretched. Other nuclei of the covering epithelium appear to be connected each with two processes, one extending, like the ordinary supporting fibers, inward through the outer nerve, and the other, outward across the epineural space.

Inner band.— The inner band, as in other holothurians, is composed of the same sorts of cellular elements as the outer band. The nuclei of the covering epithelium send outward processes which abut against the connective-tissue partition. I have not observed in Caudina processes extending in the opposite direction, across the hyponeural canal, such as are shown in Cuénot's figures of Synapta (Planche 28, fig. 48).

Connective-tissue partition.— An extremely thin layer of connective tissue separates the outer from the inner nerve band in Caudina. It is composed of fibers which arise from the connective-tissue layer on either side of the radial nerve, and at intervals contains nuclei. But it is so thin in places that one is not surprised at Hamann's denying its existence. According to this author previous observers had been deceived by an optical illusion. Although the connective-tissue partition was also overlooked by Jourdan, who in fact did not recognize that the radial nerve is made up of an outer and an inner band, it has been described by Semper, Teuscher, Semon, and Hérouard in Synaptidae, Holothuriidae, and Cucumariidae.

c. Neural Canals

Hyponeural[1] *canals.*— The existence of five radial neural canals lying immediately below the five radial nerves, first made known by Semper ('68) and Greeff ('72), has been noted by Teuscher ('76), Théel ('82), Semon ('83), Hamann ('84), Hérouard ('89), Ludwig und Barthels ('91), and others, so that their presence has been satisfactorily demonstrated throughout the whole group of Holothuroidea. The anterior ends of these canals were regarded by Semper as terminating blindly behind the nerve ring. Hérouard also has described them in the Cucumariidae as ending blindly at a point immediately behind the nerve ring, adjacent to the peripharyngeal space. In

[1]It seems to me best to abandon the name pseudohaemal vessel, which Ludwig has given to this canal in deference to the improbable idea of earlier investigators that it functions as a blood vessel, and to adopt a name suggested by its position.

Caudina likewise I have found that each canal accompanies the radial nerve as far as the point at which the latter joins the nerve ring; here it ends blindly.

Teuscher and Semon maintain, on the contrary, that the hyponeural canal is in connection anteriorly with a circular canal which lies on the opposite side of the neural band. In the figure of the circular canal given by Teuscher (Taf. 22, fig. 6) it lies on the axial and anterior side of the nerve ring. Thus it is clear that these investigators regarded the hyponeural canal as being connected with the anterior part of what we now know to be the radial epineural canal and the epineural ring canal.

The anatomical studies of Ludwig und Barthels ('91) on the Synaptidae having shown that radial ambulacral canals are wholly lacking in this family, we must regard Hamann's *radial Wassergefässe* in Synapta as hyponeural canals. Each of these has been traced forward by Hamann, as will be remembered, to a small and short canal which ends blindly behind the nerve ring and which, according to his description, is in connection with the tentacles. It seems probable, in view of the researches of Ludwig und Barthels, that he has erred in regarding this canal as connected with the tentacular canals, and that the conditions in the Synaptidae are in this particular not unlike those in the Cucumariidae and Molpadiidae.

Epineural canals.—The epineural canal described and figured by most observers who have studied the nervous system in holothurians, has been regarded quite generally as the result of an artificial separation of the external face of the radial nerve from the connective-tissue layer of the body-wall. Greeff ('72) and Hérouard ('89) are, so far as I know, the only investigators who have stated decidedly that the radial epineural spaces in the adult are not the result of artificial breaks between nervous and connective tissue, but normal cavities.

I am of the opinion, that the epineural canals in Caudina are normal structures, containing in the living animal a fluid similar to that in the body-cavity. It may be thought, that the fibers which arise from the nuclei of the covering epithelium of the anterior part of the radial nerve and pass across the epineural space into the adjacent connective tissue are evidence of an artificial separation of the tissues. The uniformity in the appearance of the wide epineural spaces in specimens fixed when the walls of

the body were not under tension, and the presence of a layer of flat epithelial cells lining the epineural spaces everywhere, except on the side occupied by the nerve band, prove conclusively, it seems to me, that these are normal cavities. The fibers which pass across the radial epineural canal are similar to the transverse fibers of the covering epithelium which pass through the nerve bands; and it is probable that the former, as well as the latter, serve as a support for the nerve band.

The radial epineural canals are continuous in front with a circular canal which lies anterior to the nerve ring. Cross sections through the nerve ring uniformly show this circular canal (*e'n. crc.*, Plate **3**, fig. 42; Plate **4**, fig. 44). Although most observers have overlooked it entirely, J. Müller ('50) and Teuscher ('76) apparently observed it, although their interpretation of the relations of the neural canals to the radial nerves and to the nerve ring are inaccurate. Hérouard ('89) found in Cucumaria a similar space, and states expressly that "*L'espace extra-nervien qui existe sur toute la longueur de chaque bande nerveuse externe se continue aussi au-dessus de l'anneau nerveux.*" Cuénot ('91), on the other hand, states that there is no circular epineural canal, and that the radial epineural space terminates blindly at the two extremities of the radial nerve. He presents no evidence, however, in support of this assertion. Ludwig ('91[b]) has followed the process of the formation of the epineural space in Cucumaria Planci. The nerve bands appear at the end of the fourth day as a ring-shaped thickening of the superficial ectoderm around the mouth, with five radial ectodermic thickenings running out from it. This fundament of the nervous system, composed of the deeper cells of the ectoderm, later cuts itself off from the more superficial portion of this layer, and by sinking down away from the surface gives rise between the nervous layer and the permanent ectoderm to a fissure-like space, which is destined to become the epineural cavity. This condition he finds both along the radial bands and along the nerve ring. The process is clearly not one of invagination, and hence the epineural canals of holothurians can hardly be regarded as homologous to those of echinoids and ophiurans, which owe their origin, as is believed, to a real invagination.

Function of the neural canals.— The most probable view hitherto advanced as to the function of the neural canals seems

to me to be that of Semon, who has suggested that they serve, when filled with fluid, as they normally appear to be, to protect the central nervous system against injuries incident upon violent contractions of the body-wall. The absence of the stainable coagulum in the canals, which are lined with a flat epithelium like that of the body-cavity, distinguishes them from the genuine haemal lacunae. The fact that the hyponeural canals are closed and isolated vessels indicates, at any rate, that they cannot be of value as circulatory organs.

2. PERIPHERAL NERVES.

a. Nerves arising from the Nerve Ring.

There are in Caudina fifteen nerves arising from the posterior part of the abaxial side of the nerve ring and ten buccopharyngeal nerves, which spring from the axial side of the nerve ring immediately behind the circular furrow in its anterior face.

(1) *The tentacular nerves* resemble in their essential features those of other holothurians in which they have been described. Each nerve (Plate **4**, fig. 48, *n. ta.*) begins as a wide sheet, which is crescentic in cross section, the concavity being directed toward the axis of the tentacle. It is thickest at the base of the tentacle, gradually diminishing toward the tip of the tentacle in consequence of the distribution of branches from it to the epithelium. The histological conditions of the tentacular nerve resemble those of the nerve ring and the outer band of the radial nerve. An anterior prolongation of the epineural ring canal accompanies each tentacular nerve for a short distance on its axial side (Plate **3**, fig. 42).

From the tentacular nerve are distributed (a) solid branches of nerve fibrillae, containing ganglionic cells, which run directly to sensory buds (Plate **2**, fig. 16), and (b) isolated fibers, which are connected with subepithelial ganglionic cells; these in turn are doubtless connected with the sensory epithelial cells. These various structures have already been described in connection with the epithelium of the integument.

Though I have spent much time in endeavoring by the Golgi method to ascertain the manner in which the members of this group of neurons are connected, my efforts have been unsuccess-

ful, and even their connection, though most probable, is still largely a matter of inference. Hamann ('84) found in maceration preparations that epithelial sensory cells in the sense papillae of Synapta are directly continuous with subepithelial ganglionic cells (Taf. 1, fig. 9), but the matter needs further investigation.

(2) *The ten buccopharyngeal nerves* (Plate **4**, fig. 44) run radially inward from the nerve ring, through the deeper part of the connective tissue of the buccal region and immediately anterior to the buccal sphincter to the lip. The main portion of each nerve, lying against the axial face of the sphincter, runs thence backward through the connective-tissue layer of the pharynx. The buccopharyngeal nerves distribute branches to the buccal, radial, and sphincter muscles, to the epithelium of the peristome, and to the muscles and epithelium of the pharynx (Plate **4**, figs. 44, 49). The buccopharyngeal nerves consist of parallel fibers, among which are interspersed the nuclei of ganglionic cells. They do not possess the covering epithelium with supporting fibers which are found in the tentacular nerve trunks and the central nervous system.

The distribution of buccopharyngeal nerves in the interradii, as they arise from the nerve ring, is seen by the following table:—

	Left-ventral.	Left-dorsal.	Dorsal.	Right-dorsal.	Right-ventral.
Number of buccopharyngeal nerves	2	2	3	2	1
" " tentacles	3	3	4	3	2

In case there are three tentacles in the right-ventral interradius and two in the left-ventral interradius, as is true of about half the specimens examined in reference to this point, the number of buccopharyngeal nerves in these two interradii respectively would probably be reversed.

A conical protuberance of the nerve ring was found in one specimen in a series of cross sections through the anterior part of the body (Plate **4**, figs. 45, 47). As series of sections through the same region in three other cases did not show any structure similar to this, it is to be regarded, for the present at all events, as an abnormality. It has the shape of a hollow cone, the apex of which is directed forward. One side of the base arises from the posterior part of the abaxial side of the nerve ring, just at the right of the origin of the right-dorsal radial nerve. It runs forward through the connective-tissue

layer, gradually diminishing in diameter, till it terminates, just beneath the external epithelium of the peristome. The correspondingly tapering lumen, posteriorly continuous with the body-cavity, ends blindly within the apex of the cone. The base of the cone (Plate **4**, fig. 45) is incomplete on its abaxial side, connective-tissue fibers there crowding up into its lumen, which is thus partially filled.

This nerve protuberance consists of exactly the same kind of elements as the nerve ring. Nerve fibrillae run through it longitudinally; nuclei, comparable with those of the covering epithelium, are distributed over its outer surface, and from them arise the ordinary supporting fibers, which run radially toward the central lumen of the cone, against the wall of which they terminate.

The lumen, which in the specimen examined contains numerous blood corpuscles, is continued behind the junction of cone and nerve ring by a wall composed of (1) an inner layer continuous with the peritoneal epithelium, (2) longitudinal muscle fibers, and (3) the connective tissue of the integument.

In the specimen in which this conical nerve protuberance was found the tentacles and other parts of the aquapharyngeal bulb were in all respects normal.

b. Nerves arising from the Radial Bands.

Although I have found it difficult to determine the exact distribution of all the nerve fibers which lie in bundles on either side of the radial nerve, it can be distinctly seen that the inner nerve band distributes fibers to the transverse (Plate **4**, fig. 43) and longitudinal muscles of the body-wall, whereas the outer band innervates chiefly the integument. Both the inner and outer bands, moreover, furnish a rich supply of nerve fibers to the walls of the rudimentary lateral ambulacra. (Plate **6**, fig. 79).

As regards the distribution of its fibers, the inner nerve band in Caudina resembles the corresponding layer in ophiurans and echinoids, for in both of these groups, as Cuénot ('91) has shown, it distributes its branches to muscles. It should be noted, however, that in the Cucumariidae and Holothuriidae Hérouard has found that the internal layer innervates to a large extent the integument, and Cuénot also finds that it takes part with the external layer

in sending nerves to the periphery of the body. Whether this *couche profonde* is homologous in the holothurians, echinoids, ophiurans, and star-fishes, can be decided only after more thorough investigations into its development in these various groups than have hitherto been made.

6. DIGESTIVE SYSTEM.

I shall first give an account of the general morphology of the digestive tract and then describe its histology.

1. GENERAL MORPHOLOGY.

The *mouth*, as in all the Molpadiidae as far as known, is circular and occupies a central position at the anterior end of the body. The epithelium of this region is similar to that of the body-wall elsewhere, but the connective-tissue layer attains, when the animal is expanded, more than ordinary thickness. That part of the connective-tissue layer which lies immediately beneath the epithelium, and also that immediately in front of the buccal sphincter (Plate **4**, fig. 44), is composed of closely packed fibers, parallel to the surfaces which they accompany; whereas loose fibers without definite direction fill the intermediate space.

The sphincter of the mouth (Fig. 44, *spht. buc.*) is a modification of the circular pharyngeal muscle layer, as in holothurians generally; immediately behind the connective tissue of the buccal region this layer spreads out like the mouth of a trumpet to form a thin flat ring. The most distal of the concentrically arranged fibers are only slightly removed from the axial margin of the nerve ring.

Radial muscle fibers (Fig. 44, *mu. r. buc.*), which oppose the action of the circular ones and lie immediately behind them, extend from the wall of the pharynx to the axial wall of the tentacle, where they are attached. These fibers do not form a continuous layer, but are either isolated or in small groups.

The *pharynx* extends from the mouth to the circular water canal, where, without any marked constriction, it joins the stomach. It gradually diminishes in caliber from before backward, and is provided with the usual internal longitudinal ridges. The outer surface is

not raised into wart-like protuberances or papillae, as described in some species of Cucumaria, but is smooth. The suspensors, which are a continuation of the external connective-tissue layer of the alimentary tube, are arranged in ten longitudinal rows upon the surface of the pharynx, from which they pass through the peripharyngeal cavity to the wall of the calcareous ring. They contain muscle fibers which serve as dilatators of the pharynx.

The *stomach* is a short, straight tube 1.5 cm. in length, of a uniform diameter of about 3 mm., and of a whitish color. It extends from the ring canal to a point just behind the region where the reproductive tubules unite. A constriction separates it from the small intestine. The outer surface is smooth; the inner surfac is raised into irregular, rounded prominences. Its walls are slightly thicker than those of the succeeding portions of the alimentary tube.

In *Cucumaria frondosa*, as I have made out, the walls are very thick compared with those of the small intestine, and by this fact, as well as by the small and uniform caliber of the stomach, the two parts are well marked off from each other. Quatrefages ('42) and Kingsley ('81) are the only writers on holothurians who, so far as I know, have failed to note this differentiation into stomach and intestine. The distinction might readily be overlooked in Caudina, but it is very obvious in Cucumaria.

In a fresh specimen the *small intestine* (Plate **4**, fig. 46) is easily distinguished from the stomach and the large intestine by its reddish color, which is due to the very abundant blood supply. It extends backward about one third of the length of the animal, turns to the left side of the body, and runs forward as far as the posterior end of the stomach, where it joins the large intestine. The small intestine of Caudina resembles that of other holothurians in the thinness of its walls and in the presence of irregular transverse folds, which occur upon the outer surface. The inner surface is likewise thrown up into numerous transverse folds, which are smaller and more abundant than those upon the external surface.

The *large intestine* differs from the small intestine mainly in its paler color and larger caliber. It turns sharply near its beginning, and runs backward on the ventral side of the other viscera to the cloaca, which begins nearly opposite the bend in the small intestine.

The *cloaca* is much dilated anteriorly, in the region where the respiratory trees branch off from it on either side; from this point backward to the anus it gradually diminishes in caliber. Numerous strands consisting of muscle fibers and connective tissue attach the cloaca to the body-wall.

The line of attachment of the *mesentery* which supports the stomach and the small intestine in Caudina is remarkable only for the fact, that it is closely approximated to the longitudinal muscles alongside of which it runs, a condition which has been noted by Jaeger ('33) in various forms of Holothuriidae and by Semper ('68) in Chirodota. The mesentery itself is an unbroken sheet, which may be described under the two divisions called by Ludwig ('89–'92) the dorsal and the left. The *dorsal* division is attached to the right side of the dorsal interradius. At the bend in the small intestine the line of attachment of the mesenteries turns to the left side of the body and runs forward in the left-dorsal interradius as far as the end of the small intestine, being closely approximated to the left-dorsal radial muscles. This part of the mesentery is the *left* division of Ludwig. From this point the line of attachment of the mesentery bends sharply to the left and crosses the left-ventral and median-ventral radii into the right-ventral interradius, where near the anterior end of the small intestine it abruptly terminates; the third or *right* division of the mesentery, which, as is well known, is attached along the right-ventral interradius, is therefore not represented in Caudina, except at the very beginning of the large intestine.

Two sheets composed of separate muscular strands arise in the right-dorsal and left-dorsal interradii close to the right-ventral and left-ventral radial muscles. They serve to support the large intestine.

Between the two layers of peritoneal epithelium of the mesenteries there are found, besides connective tissue, isolated muscle fibers running in various directions.

2. HISTOLOGY.

The alimentary tube throughout its whole extent consists of five layers of cells, which from without inward are (*a*) an outer layer of peritoneal epithelium, composed of ciliated cells, (*b*) a thin outer layer of connective tissue, (*c*) a layer of muscle fibers, which in turn consists of two layers, except in the pharynx, (*d*) a thick inner layer of connective tissue, and finally (*e*) the columnar epithelial lining of

the tube. The last is covered with a hyaline structureless cuticula, except in the small intestine.

(*a*) *The peritoneal epithelium* of the alimentary tube is ciliated throughout its extent. It consists of cubical cells, which, treated with silver nitrate, present somewhat regular polygonal outlines (Plate **5**, fig. 56). The diameter of the cells (10–16 μ) is about the same as that of the epithelial cells of the reproductive organs, to be described later.

In *Cucumaria* (Plate **5**, fig. 53) the external epithelium of the stomach is composed of spindle-shaped cells, the deeper portions of which run through a layer of connective tissue, on the inner surface of which they terminate.

(*b*) The *outer layer of connective tissue* underlying this external epithelium in Caudina is so extremely thin as to be scarcely noticeable except in the wall of the stomach.

(*c*) The *muscle layer* consists in theanterior part of the pharynx of circular fibers only; at about the middle of the length of the pharynx longitudinal muscle fibers are inserted in the connective tissue beneath the layer of circular muscle fibers. These longitudinal fibers increase in number from in front backwards, and throughout the extent of the stomach and small intestine form a continuous sheet immediately beneath the layer of circular muscle fibers. Whereas the latter is well developed from mouth to anus, the longitudinal muscle fibers are scanty in the small and large intestines and entirely absent in the cloaca. They are functionally replaced here, however, by about twenty isolated longitudinal muscles of small size (Plate **5**, fig. 61, *mu. lg.*) lying externally to the band of circular muscles of the cloaca and disposed at irregular intervals in the external layer of connective tissue.

The numerous strands attaching the cloaca to the body-wall are composed of connective tissue in which are embedded radial muscle fibers. Each strand has a covering of peritoneal epithelium.

In *Cucumaria frondosa* I have found the arrangement of the two muscle layers in the wall of the alimentary tube to be the same as in Caudina, *i. e.*, the longitudinal fibers lie within the circular muscle layer (Fig. 53).

The same arrangement of muscle layers has been found in all the Molpadiidae and Cucumariidae thus far studied. In Holothuria,

however, Hamann ('84) has found that, although the arrangement of muscle layers in the pharynx and stomach is the same as in Caudina and Cucumaria, in the small and large intestines the longitudinal muscle layer lies outside the layer of circular fibers.

The muscle fibers of the pharynx in Caudina (Plate **2**, figs. 13 and 14), like those of Synapta as described by Hamann, differ from those of the longitudinal and transverse muscles of the body-wall in that they are more slender. In Caudina the formative cell and the nucleus, which is oval and about 7 μ in length, are situated upon one side of the axis of the fiber (Fig. 14). The earlier statement of Hamann ('83), that in Synapta the nucleus is embedded within the contractile substance, has since been acknowledged by him ('84, p. 95) to be incorrect.

In Caudina the structure of these muscle fibers affords no indication that they have developed from mesenchyme cells. Ludwig ('91b), moreover, expresses the opinion that these fibers in Cucumaria Planci, the ontogeny of which he has investigated, are certainly not mesenchymatous in origin, but are derived from cells of the enterocoel which lie closely against the wall of the primitive pharynx (*Vorderdarm*). On the other hand, Selenka ('83) states that the circular muscle fibers arise from mesenchyme cells, and Semon ('88) likewise finds that in Synapta both the circular fibers and the underlying longitudinal fibers are mesenchymatous. The mesenchyme cells apply themselves to the wall of the primitive pharynx in the Auricularia stage, and send out two or more processes in the direction of the future muscle fibers; the processes of the different cells unite; and thus, while each fiber is the product of several cells, a single cell takes part in the formation of several fibers.

Further investigations into both the structural conditions and the development of the muscle fibers in holothurians are necessary in order to prove whether they arise in part from mesenchyme. Hamann's description of the circular pharyngeal fibers in Synapta does not furnish any evidence whatever to corroborate the statements of Semon just given as to their origin and structure in the larva. Metschnikoff ('84) denies that they arise from mesenchyme in Synapta, and Ludwig, as already stated, is decidedly of the opinion that in Cucumaria they arise from cells of the peritoneal epithelium. Finally, my studies of the circular fibers both of the pharynx and reproductive tubules of the adult Caudina afford me

no reason for believing that in this form there are mesenchymatous muscle fibers.

(*d*) The *inner layer of connective tissue*, the fourth layer of the wall, is well developed throughout the whole extent of the alimentary tube in Caudina; it is everywhere the thickest of the layers. It closely resembles the connective tissue of the integument, except that it is less compact. Bipolar or stellate cells, like those of the body-wall, are found at intervals, and the various sorts of wandering cells, to be described in connection with the internal epithelium, are abundant. In the small intestine great blood-spaces occur in this layer (Plate **5**, fig. 54).

I have found that in Cucumaria frondosa the stomach is entirely without an internal layer of connective tissue (Plate **5**, fig. 53). This is in accord with the observation of Hamann, that in Cucumaria cucumis and C. Planci, this inner layer of connective tissue, everywhere so well developed in Caudina, is lacking in the pharynx and insignificant in amount in the wall of the stomach, though reappearing in the small intestine.

The absence of such a layer, which is everywhere the bearer of wandering cells connected with digestion, and in Caudina is the channel by which blood corpuscles come into connection with the internal epithelium, is readily explained. The thick lining of cuticula, the extremely muscular walls of the stomach of Cucumaria, as well as the absence of gland cells and amoebocytes, clearly indicate that the function of the stomach in Cucumaria is to triturate the food rather than to assist in its absorption. Hence the lack of the connective-tissue layer in this genus.

(*e*) The *inner epithelium* is composed of columnar supporting cells interspersed with gland cells; between these are found wandering cells.

a. *The epithelium of the pharynx* (Plate **5**, fig. 51) consists of cylindrical cells — the deep ends of which are not well marked off from the connective-tissue layer — and long tubular gland cells, which are of two or three times the length of the supporting cells. A thin cuticula lines the pharynx.

The deep ends of the gland cells are often enlarged by an oval swelling. An elongated, diffusely staining nucleus embedded in a small amount of protoplasm is found flattened against the

side of the unicellular gland, the contents of which appear in sections as vacuolated matter of a fibrous nature. These cells correspond to the tubular gland cells of the epidermis.

Wandering cells of two kinds are found in the wall of the pharynx. They are (1) the ordinary spheruliferous corpuscles (Plate **5**, fig. 51, *cp. sph.*) and (2) amoeboid cells (Plate **5**, fig. 51, *cl. vag.*). These differ from the former in two respects; they stain diffusely with haematoxylin, instead of absorbing eosin, and are composed of homogeneous protoplasm without spherules. The second form of wandering cell is probably a modification of the first.

β. *The epithelium of the stomach* (Plate **5**, fig. 52) is made up of columnar supporting cells, about 50 μ in length surmounted by a very thin cuticula. Oval nuclei (5.5 μ by 3.6 μ) each with several nucleoli, are found at various heights between the attached and free ends of the epithelial cells. These cells often have a vacuolated appearance, the free extremity of the cell containing a greater amount of granular protoplasm — which stains deeply with eosin— than the deeper part of the cell. Spaces between the supporting cells indicate the position of gland cells.

Wandering cells of two sorts are also found here: (1) the ordinary clear, spheruliferous corpuscles (Plate **5**, fig. 52, *cp. sph.*), which are very abundant in the underlying stratum of connective tissue and are found even at the surface of the epithelium, and (2) cells containing smaller spherules or granules; these are denser and consequently more deeply colored in stained sections (Fig. 52, *cp. sph.'*).

γ. *The epithelium of the small intestine* (Plate **5**, figs. 54 and 55) consists of slender cylindrical cells about 40 μ in length. The basal half of each cell, in which the nucleus is situated, consists of dense protoplasm, whereas the free end either presents a vacuolated appearance or contains protoplasm of a thin consistency, staining less deeply than the contents of the basal part of the cell. The cell outlines are everywhere sharp.

There is no clear continuous cuticula over the epithelium of the small intestine, such as is found elsewhere in the alimentary tract, but in place of it each cell is capped with a dome of homogeneous material which stains deeply with eosin, so that sections of the epithelium show a notched outline. Clear spheruliferous bodies are to be seen in this epithelium, and rarely I have found in fresh material a bright red, spheruliferous, wandering cell, which I suppose to be

one of the red secreting cells found by Frenzel ('92) to be common in the small intestine of Synapta, Strongylocentrotus, and Holothuria tubulosa. Frenzel thinks these may represent the beaker-like gland cells of Hamann. I have not found special gland cells in the small intestine. I infer from the absence of gland cells and the great development of the blood sinuses connected with this part of the alimentary tract, that it is concerned solely with absorption.

δ. *The epithelium of the large intestine* resembles closely that of the part of the alimentary canal just described. The cells have each a similar, deeply-staining cuticular cap, but the whole tract lacks the extensive blood supply of the small intestine.

The epithelium of the cloaca (Plate **5**, fig. 62) is composed exclusively of columnar cells, whose nuclei occupy the middle or basal portion of the cell. In the tail region it is about 29 μ thick, and is provided throughout with a thick cuticula. The ordinary spheruliferous bodies are abundant in the subjacent layer of connective tissue.

7. THE RESPIRATORY TREES.

Opening into the cloaca on either side, at points a little behind the bend in the small intestine, are the two respiratory trees (Plate **4**, fig. 46); they are quite distinct from each other. Both trees run forward to the region of the aquapharyngeal bulb.

The left tree divides near its attachment into two main branches, one of which follows, and is intimately connected with, the left perforated mesentery of the large intestine, and therefore may be called the ventral branch, while the other lies in the anti-mesenterial blood plexus of the small intestine, and may be distinguished as the dorsal branch. The right tree consists of a single trunk; this lies partly in the meshes of the right mesentery of the large intestine, which it accompanies. Anteriorly it crosses on the dorsal side of the aquapharyngeal bulb to the left side of the body, where it soon ends blindly.

Kingsley probably did not recognize the dorsal branch of the left tree, for he neither described nor figured it; hence he concluded that the right tree is the larger; if, however, both branches of the left tree be taken into consideration, the left much exceeds the right in size.

Like Kingsley, I have been unable to find in Caudina any perforation at the tips of the branches of the respiratory trees, such as were described by Semper for other holothurians and have been mentioned by Sluiter ('87), and Hamann ('84). Ludwig and other observers have also searched in vain for such perforations.

In both Cucumaria and Caudina the opening and closing of the anus, which attend the contraction and relaxation of the muscles of the respiratory trees in admitting and expelling water, take place at quite regular intervals.

The respiratory trees in Caudina, as in other holothurians, consist of the same cell layers (Plate **5**, fig. 58) as constitute the wall of the intestine, viz.: —

(*a*) A layer of flat, ciliated, peritoneal cells (*e'th. ex.*) with more irregular and sinuous outlines than those of any other of the cells lining the body-cavity (Plate **5**, fig. 59).

(*b*) A relatively thin outer layer of connective tissue (*tis. con't. ex.*).

(*c*) A layer of muscle fibers (*mu.*), which run in all directions parallel to the surface of the respiratory tree. (A similar condition was found by Jourdan in Cucumaria Planci; whereas both Semper and Hamann found in Holothuria tubulosa two layers, corresponding to those of the intestine; *i. e.*, an inner layer of longitudinal fibers and an outer one of circular fibers.) The inner fibers of this muscle layer in Caudina have a circular direction and are more numerous than the outer oblique and longitudinal fibers.

(*d*) A thick inner layer of connective tissue (*tis. con't. i.*), consisting of a larger proportion of the hyaline, homogeneous matrix than in the connective tissue of the wall of the body, and containing fine fibers and stellate cells.

(*e*) An inner epithelium, which is often thrown into great folds by the contraction of the muscle fibers

8. CALCAREOUS RING.

The term aquapharyngeal bulb has been applied by Hérouard ('89) to the bulb-like collection of organs suspended within the anterior part of the body-cavity, including the pharynx, the central portion of the water-vascular system and the lacunar vessels accompanying the central portions of the radial canals. I shall now describe the

calcareous ring which forms the framework of the aquapharyngeal bulb. It is composed, as in all known Molpadiidae, excepting perhaps Trochostoma,[1] of ten pieces (Plate **5**, figs. 64 and 65), five radial plates alternating with five smaller ones situated in the interradii. They are so closely bound together that they cannot be readily separated, except by the use of a solution of potassium or sodium hydrate. Each radial plate, as seen in looking upon its outer surface (Fig. 65, *b*), is of a somewhat hexagonal shape, tapering anteriorly and posteriorly from near the middle; its length (6–7 mm.) is twice its greatest breadth (3–3.5 mm.), and its thickness is about 1 mm. The plate is slightly notched in front to admit the radial water-tube at the point where the tube turns to run outwards to the body-wall; posteriorly the plate is forked. When viewed edgewise (Fig. 65, *a*), the plate is seen to be slightly concavo-convex. The external surface of the anterior part of each radial piece is slightly corrugated on one side for the attachment of the longitudinal muscles of the body-wall, and furrowed on the other side to receive a tentacular ampulla. The internal surface (Fig. 65, *c*) has a shallow furrow, running parallel to the long axis of the plate along its median line, which accommodates the radial canal as it runs forwards from the circular canal of the water-vascular system.

Although the configuration of the external surface of the radialia in Caudina is not so irregular as in many holothurians, yet the structure is to a considerable extent modified in adaptation to the overlying tentacle on one side and the termination of the longitudinal muscle on the other. The position of tentacle and radial muscle in respect to each other results therefore in the symmetry of radialia already described by Ludwig ('89–'92, p. 87–88; '91[a]; '91[c]). As in other Molpadiidae and in some Cucumariidae, the two right radial plates in Caudina arenata are congruous with each other, each having against the anterior part of the external surface a tentacle dorsad, a muscle ventrad; likewise the two left radialia are congruous with each other, *i. e.*, a tentacle dorsad, a muscle ventrad; consequently the radialia of the right side are symmetrical with those of the left both in position and form. The median, ventral radial plate in C. arenata may be congruous with the right radial plates, and therefore symmetrical with the left ones, as in the East-Asiatic Caudina

[1] Ludwig ('89–'92) states (p. 82–83) that T. arenicola has only the five radial plates; in T. oölíticum the plates are absent altogether.

described by Ludwig ('91c) and in several Molpadiidae and Cucumariidae that have been examined; or the ventral plate may be congruous with those of the left side and symmetrical with those of the right. The former I believe to be somewhat the more frequent condition in Caudina arenata, but the latter is of common occurrence. A similar variability in the ventral radial plate in the case of Ankyroderma musculus has been described by Ludwig ('91a).

The outer and inner surfaces of each interradial plate (Plate **5**, fig. 64, *a* and *b*) are wedge-shaped, slightly convex and concave respectively. In length the interradialia measure 3–3.5 mm., in breadth at the anterior or broadest part 2 mm., in thickness nearly 1 mm. The external surface is provided with two furrows in which lie tentacular ampullae.

Both radial and interradial plates consist of individual spicules (Plate **3**, figs. 20–24), closely massed together and interlocked, the interstices being filled with fibrous connective tissue. There is a superficial layer on both axial and abaxial sides of a plate which consists of irregular, richly branching spicules (Fig. 20) so interlocked as to form a loose network. The central portion of the plate, which is much thicker than the superficial layer consists of long, slender, dichotomously, branching spicules (Figs. 21–24), which may branch as many as three or four times. The branches make a very small angle with the stem from which they arise, so that the spicule as a whole is much elongated. The chief axes of these spicules are parallel to one another and to the long axis of the radial plate. A branching spicule may attain a length of 300 μ, whereas the stem of the same spicule is only 5–6 μ in diameter.

9. WATER-VASCULAR SYSTEM.

1. ANATOMY AND HISTOLOGY.

The vessels of the water-vascular system in Caudina arenata consist of (*a*) the circular canal, (*b*) the stone-canal, attached to the circular canal in the dorsal interradius and terminating in a madreporic body, (*c*) the single Polian vesicle, opening into the circular canal from behind in the left-ventral interradius, and (*d*) the five radial canals, which proceed from "*a*" anteriorly. Each of these five canals runs forward in the previously described groove on the

axial side of a radial calcareous plate, sends off three tentacular canals, bends outward at the anterior extremity of the aquapharyngeal bulb (Plate **5**, fig. 67), and then runs backward between the hyponeural canal and the body cavity to the tip of the tail, where it terminates in three blindly ending branches. Of these branches one is median and two lateral, the former lying in an anal papilla, the latter embedded in the connective-tissue layer of the body-wall. After describing these parts I shall treat of (*e*) the tentacles.

The supposed rudimentary ambulacra of Caudina and other Molpadiidae described by previous authors having been discussed under "Integument," — in connection with which certain somewhat problematical structures in Caudina are described, — I shall confine my attention in this part of the paper to certain unquestionably rudimentary ambulacra, which I have discovered in connection with (*f*) the three posterior branches of the radial canal.

a. Circular Canal.

The circular canal (Plate **5**, fig. 66) surrounds the pharynx immediately behind the calcareous ring, and is situated as far from the wall of the pharynx as are the posterior extremities of the radial plates, to which its anterior wall is attached. Strands of connective tissue covered with epithelium pass from the axial side of its wall to that of the pharynx and thus form a further support. The diameter of its lumen measures nearly or quite 1 mm. Its wall (Plate **6**, fig. 76), though relatively very thin (13–20 μ), is composed of five layers. These from without inward are (1) a flat, ciliated endothelium, (2) a comparatively thick layer of connective tissue, (3) an exceedingly thin hyaline, structureless membrane, separating "3" from (4) a thin layer of muscle fibers, which are circular, *i. e.*, lie in planes perpendicular to the direction of the canal,[1] and finally (5) an internal epithelium composed of flat ciliated cells.

The connective tissue is composed of fibers — for the most part running parallel to the direction of the canal — embedded in the usual transparent matrix, which here is especially abundant. Stellate connective-tissue cells are scantily present; spheruliferous corpuscles in great numbers. The circular muscle fibers are continuous

[1] I find that in Cucumaria frondosa the muscle fibers are not parallel to the direction of the canal, as Semper ('68, p. 123) asserts, but perpendicular to it.

with those of the radial vessels and with certain others which lie in the connective tissue on the outer side of the posterior end of the radial plates.

b. Stone-canal and Madreporite.

There is in Caudina, as in all other Molpadiidae, so far as is known, a single stone-canal (Plate **1**, fig. 3; Plate **5**, fig. 66; Plate **6**, fig. 73), which opens into the circular water-canal in the median-dorsal interradius. It is an irregularly twisted tube embraced within the two layers of the dorsal mesentery; its general direction is forward and dorsad; it terminates in a whitish rosette-like or heart-shaped madreporite. The length of the irregular coil into which the stone-canal is wound is about 1.75 mm.; the total length of the canal may be estimated to be from four to five times as much, and its diameter is about 0.2 mm.— its lumen 0.06 mm. At the point where the stone-canal joins the circular canal (Plate **5**, fig. 66) the dorsal mesentery is not connected with the aquapharyngeal bulb, so that the stone-canal and madreporite are suspended in the mesentery near its ventral margin; anterior to the madreporite the ventral edge of the mesentery encloses the genital duct.

The madreporic body (Plate **1**, fig. 3, *mad.*) is situated upon the left, or rarely upon the right, side of the tip of the stone-canal, at a point immediately ventral to the genital duct. It has been described briefly by Kingsley as rosette-shaped. The general outline of it, however, is not circular, but oval or often heart-shaped; in the latter case the apex points forward and slightly dorsad toward the genital duct. It presents two surfaces, a mesenterial, which is nearly flat (the stone-canal arises from the posterior half of this face), and an antimesenterial, upon which most of the passages traversing the madreporite open into the body-cavity. The latter surface has only a slight convexity in the antero-posterior direction, whereas in the direction at right angles to this it is often highly convex.

The surface is covered with meandering furrows of varying length,— in some cases mere pits,— at the bottom of which the outer openings of the pore canals are found. These channels, as I have determined by a plastic reconstruction, may open into the narrow central chamber of the madreporite without branching, or 2–4 of them may unite and have a common opening into the central chamber (compare Plate **6**, fig. 74). The central chamber is flat-

tened parallel to the broad surfaces of the madreporite, so that it may be as much as 170 μ wide, whereas its depth is generally much less, viz., 40–60 μ, although in places it may be as much as 125 μ deep.

Histology. — The wall of the stone-canal (Plate **6**, fig. 73) is composed of a thick layer of fibrous connective tissue containing connective-tissue cells but no muscle fibers, covered externally with the peritoneal epithelium of the mesentery and lined with an internal ciliated epithelium; on one side of the tube this is composed of high, cylindrical cells, on the opposite side the cells are low and cubical. The transition between the two kinds of cells is gradual. The stone-canal of Caudina differs from that of most holothurians in that there are no calcareous bodies in its wall.

The statement of Hamann, that the low, cubical cells of the internal epithelium are found on the side of the tube next the supporting mesentery, and the high, cylindrical ones on the opposite side, has been called in question by Ludwig ('89–'92, p. 134), who examined several forms of holothurians, including Caudina, in reference to this matter. In studying several series of sections through the stone-canal of Caudina I have found that the low, cubical cells, of a height of only about 4 μ, are uniformly on the side of the canal which is next the mesentery and that they increase gradually in height up to about 32 μ on the side directly opposite, which hangs free in the body-cavity. Thus I can confirm Hamann's statement as far as Caudina is concerned. The cilia with which the tall cells are provided are longer than those of the cubical cells. The length of the cilia is about equal to the height of the cells to which they belong.

The madreporite (Plate **6**, fig. 74), is composed, as in other holothurians, of connective tissue like that of the stone-canal. In it are numerous irregularly branching calcareous bodies (Plate **3**, fig. 25), which are found in greatest abundance near the surface of the madreporite. The arms of well-developed bodies are four or five in number and those of adjacent spicules interlock. These spicules often measure 100 μ from tip to tip of the arms. Numerous spheruliferous corpuscles are found in this layer of the wall, as well as in the channels of the madreporite.

c. Polian Vesicle.

The Polian vesicle (Plate **5**, fig. 66, *vs. Pol.*) is attached to the circular water-canal in the left-ventral interradius. It is of an

elongated oval shape, being 6–8 mm. in length and 3 mm. or less in diameter, according to the degree of contraction of the circular muscle fibers in its wall.

The wall (Plate **6**, fig. 75) is composed of (1) an outer layer of flat, ciliated peritoneal cells, (2) a thick layer of connective tissue, composed, as in the circular canal, chiefly of fibers running in a longitudinal direction, (3) a layer of circular muscle fibers, about equal in thickness to that of connective tissue, and (4) an internal epithelium of thin, flat cells. Thus in its finer structure the Polian vesicle closely resembles the circular water-canal, the relative thickness of the muscle layer as compared with that of connective tissue is, however, much greater in the Polian vesicle than in the circular canal.

d. Radial Canals.

Each radial canal in the region near its opening into the circular canal has a much larger caliber than along the rest of its course (Plate **5**, figs. 67–70, *aq. r.*); this is shown by a series of cross sections through the aquapharyngeal bulb. A cross section through the aquapharyngeal bulb where the radial and interradial plates are united into a continuous ring (Fig. 70) shows the median-ventral radial vessel (*aq. r'.*) dividing into three parts. The two lateral branches (Fig. 71, *aq. ta.*) pass forward, diverging till they reach the anterior border of the calcareous ring, where each enters a tentacle. Anterior to this point (compare fig. 67) the radial vessel gives off —in this case on the *left* side—a short branch (*aq. ta'.*, fig. 72), which is larger than the continuation of the radial canal itself, and opens into the third or most ventral tentacle; greatly reduced in caliber, the radial canal then curves outward passing through the anterior notch in the radial plate, and runs backward to accompany the radial nerve and neural vessels to the posterior extremity of the body. The branches to the tentacles may, however, be given off at three different levels instead of at two, and the branch opening into the median-ventral tentacle may arise on the *right* side of the median-ventral radial vessel (Fig. 67), instead of on the left as in the example cited. I shall refer to this matter again in treating of the arrangement of tentacles in the interradii.

The *histology* of the radial canals in Caudina (Plate **1**, fig. 1; Plate **3**, fig. 40; Plate **4**, fig. 43; and Plate **6**, fig. 79) is similar to

that in other holothurians. The wall of the radial vessel is composed of connective tissue, lined with a layer of flat, ciliated cells. Longitudinal muscle fibers exist between these two layers on one side of the vessel only; the side which, throughout the most of its course, is turned toward the exterior and is consequently adjacent to the lacunar vessel of the connective-tissue layer. A few of these fibers accompany the radial canal into the aquapharyngeal bulb, being there naturally on the inner, or axial side of the radial canal, between it and the haemal vessel. Enveloping the radial canal and lying just external to the muscle fibers is a thin, structureless, hyaline membrane.

e. Tentacles.

Arrangement in interradii.—The tentacular ampulla which passes over each of the *paired* radial plates lies dorsad to the adjacent radial muscle attached to the plate. This is coördinate with the fact that n the dorsal interradius there are four tentacles, while there are three each in the right-dorsal and in the left-dorsal interradii. In like manner each of the paired radial canals sends two tentacular branches dorsad, one ventrad; thus the three interradii of the bivium possess in all ten tentacles.

These conditions, as already pointed out by Ludwig (’91, ’91c), hold good for several species of Haplodactyla, Ankyroderma musculus and the East-Asiatic Caudina, which Ludwig has described as probably identical with C. caudata. The arrangement of the five remaining tentacles belonging to the two interradii of the trivium varies, however, in C. arenata in the same way as in A. musculus. For there may be either two tentacles in the left-ventral interradius and three in the right-ventral or *vice versa*. In the former case the median-ventral radial canal sends two branches to the right, one to the left,—a condition which obtains generally, acccording to Ludwig, in the East-Asiatic Caudina which he described; in the latter case two tentacles are of course sent to the left, one to the right.

Ludwig’s criticism (’89–’92, p. 588) of Von Marenzeller’s statement (’82) in regard to the calcareous ring of C. arenata is entirely just. The statement in brief is that, if the calcareous ring be rolled out flat and viewed from the abaxial surface, the tentacle is found to lie immediately to the right of the median line of each interradial plate, and that then comes the attachment of a muscle, whereas to the left of its median line there are two tentacles. Ludwig has already

determined that this statement is improbable, inasmuch as such a condition would necessitate the presence of three tentacles in every interradius, a condition at variance with that in other Molpadiidae; furthermore it is obvious that Von Marenzeller made an examination of only the left half of the calcareous ring of Caudina arenata, as Ludwig (*Ibid.*, p. 589) was on a priori grounds led to suppose. With the abundance of material at my disposal I have been able by direct observation to substantiate throughout the conclusions in regard to the conditions in *C. arenata* at which Ludwig has arrived.

Histology.— As the external features of the tentacles were described in connection with the integument, I pass at once to their histology. The tentacles are composed of five layers: (1) a columnar epithelium covered with a cuticula, (2) a thin layer of connective tissue, (3) nervous tissue, forming a thick band on the side of the tentacle next the axis of the body, and gradually diminishing in thickness on either side of the inner median line of the tentacle, (4) a layer of longitudinal muscle fibers, and (5) the internal epithelium.

The external epithelium of the tentacles has already been described in connection with that of the body-wall. The connective tissue does not differ materially from that of the body-wall; calcareous bodies are, however, entirely absent. A thin hyaline membrane from this layer of the tentacles overlies the layer of longitudinal muscle fibers here, as in the radial and circular canals.

Circular muscle fibers, lying outside the layer of longitudinal ones, have been described by Danielssen and Koren ('82) for the allied form Trochostoma; there are, however, no circular muscle fibers in the tentacles of Caudina, and most of the recent observers have been unable to confirm the earlier observations of Quatrefages ('42) and Baur ('64), that such fibers are found in Synapta. The internal epithelium is composed of flat, ciliated cells.

Tentacular valves.— Valves, similar to the "Semilunarklappen" which Hamann ('83) has described for Synapta, are found in Caudina. Each valve is situated in a radial canal near its junction with a tentacular vessel (Plate **6**, fig. 77); it is attached to the calcareous radial plate which forms the outer wall of the canal and, to some extent, to the connective tissue of which the side wall is composed. The valve consists, as in Synapta, of muscle fibers, radial to the chief axis of the body, which are surrounded, especially on the attached edge, with fibers of connective tissue; by the contraction of these muscle fibers the valve is drawn aside from the

lumen of the canal. The ordinary epithelium which everywhere lines the vessels of the system covers both sides of the valve. The turning of the concavity of the valve towards the tentacle and the presence of numerous blood corpuscles lying against this concave side in sections of the valve in action show that the valve serves to prevent the flow of fluids from the tentacle.

The *tentacular ampullae* (Plate **5**, figs. 66, 67) hang free in the body cavity, as in other Molpadiidae and the Cucumariidae, being attached to the anterior part of the calcareous ring for a short distance only. They are slender tubular organs about 7 mm. in length, which taper to a point and end blindly at about the level of the ring canal or a little behind it.

The anterior attached portion of an ampulla presents a different histological condition from that of the posterior blind sac. The latter has the simpler structure, being composed of (1) ordinary peritoneal epithelium, (2) a thin middle layer of connective tissue containing stellate connective-tissue cells and numerous amoebocytes, and (3) a flat internal epithelium. In the anterior or attached portion of the ampulla, but only in that part of its wall which is nearest the body-wall, muscle fibers make their appearance between the inner epithelium and the connective tissue. These have a longitudinal direction, and run forward as a thick sheet, which is continuous with the muscular layer of the tentacle.

f. Posterior Branches of the Radial Canal.

As has been already stated, each radial canal ends blindly in an inconspicuous anal papilla, homologous to the terminal tentacles in the Asteroidea, Ophiuroidea, and Echinoidea. A pair of rudimentary ambulacra (Plate **6**, figs. 79, 80) communicate by narrow openings with the radial canal near its end, where it opens into the terminal papilla. These lateral rudiments of ambulacra are situated within the connective-tissue layer and run outward nearly to the epithelium (Fig. 79), but there are no corresponding elevations of the surface of the body.

The walls of the papilla (Plate **4**, fig. 50, *pa. an.*) consist from without inward of an outer epithelium of cubical or flattened cells, a thin layer of fibrous connective tissue without spicules, in which blood sinuses similar to those found in the genital tubules arise, a hyaline homogeneous sheath enveloping a layer of longitudinal

muscle fibers and, finally, the inner epithelium, which differs from that of the rest of the water-vascular system in that the cells are thinner and flatter than elsewhere.

The paired rudimentary ambulacra present histological conditions similar to those of the ambulacral canals of holothurians generally. Their walls (Plate **6**, fig. 79) consist of a layer of longitudinal muscles enveloped by a structureless hyaline membrane, and, inside the muscles the ordinary epithelium lining the water-vascular system.

The fact that the anal papillae of Molpadiidae are, in some cases at least, ambulacra was suspected by Ludwig, who, in stating that ambulacral organs are lacking in the Molpadiidae, adds in a foot-note ('89–'92, p. 100): "Ich kann den Verdacht nicht unter-drücken 'dass die fünf kurzen, etwas ästigen Papillen', welche Semper an der Kloakenöffnung seiner Haplodactyla molpadioides beschreibt und abbildet, sich bei eingehender Untersuchung als umgewandelte Füsschen herausstellen werden."

Anal papillae, as is well known, are of quite general occurrence in the Molpadiidae. All species of the genus Haplodactyla have been shown to possess anal papillae, except the imperfectly known H. holothuroides Cuv., which Théel regards as identical with H. australis. In the genus Trochostoma the presence of anal papillae in T. arcticum, T. boreali, and T. Thomsonii, has been shown by Danielssen and Koren ('82), in T. albicans and T. antarcticum by Théel ('82), and in T. granulatum and T. intermedium by Ludwig ('94); thus they have been found in seven out of fourteen well-authenticated species of this genus. The presence of five anal papillae in the genus Ankyroderma has been given by Danielssen and Koren as a characteristic of that genus. They have, at all events, been shown to exist in every species classed in this genus, except A. limicola (Verrill), A. Marenzelleri (Théel), A. Roretzii (v. Marenz.), and A. spinosum (Ludwig). In the genus Caudina, anal papillae were not found in C. caudata (Sluit.), nor in C. Ransonetti (v. Marenz.). Théel describes in C. coriacea (Hutton) five groups of anal papillae with 5–7 papillae in each group. In Ludwig's C. californica the tail unfortunately was injured. Thus, if anal papillae are present throughout the genus Caudina, they are so small in both C. caudata and C. Ransonetti as to have eluded observation, just as they have hitherto done in C. arenata.

Among the Holothuriidae anal papillae are described in Bohadschia; among the Cucumariidae five groups of feet around the anus

in Thyone gibber (Sel.) are mentioned, and five groups of papillae in T. panamensis and Actinocucumis typica (Ludwig). Anal papillae are also described in Pelagothuria natatrix (Ludwig).

In very few of the descriptions of the anal papillae, however, has it been stated whether the papillae, or groups of such processes, are situated in radii or interradii; but in several instances in which their position has been noted, they have been found at the tips of radii. Whether in all cases they are radial, and represent terminal tentacles of the radial water-vessels, can only be determined by further observations. The structure of the papillae in Trochostoma granulatum (Ludwig, '94, p. 159) reminds one at once of the conditions in C. arenata. In the former case the anal papillae are arranged in five groups, each consisting of three small flexible processes, one of which is longer, cylindrical in shape, and median in position; the two others are shorter and situated laterally. It seems probable that we have here a condition similar to that in C. arenata, except that the papillae are longer than in the latter case, the lateral ambulacra, therefore, projecting beyond the surface of the body.

2. CONTENTS OF THE WATER-VASCULAR SYSTEM.

In the colorless, transparent, unstainable plasma of the water-vascular system, three sorts of cellular elements are found, viz.: blood corpuscles, colorless spheruliferous corpuscles, and brown spheruliferous cells.

The blood corpuscles are like those found in the body cavity and in the blood vessels of the intestine. In color they resemble the blood corpuscles of vertebrates, being light yellow when seen singly or in small groups, crimson when massed together. They are oval, often being nearly circular, though sometimes much elongated, especially in prepared sections where they are in no wise crowded; they may be bent in respect to their chief axis, also drawn out at one pole into a sharp point. From this I conclude that they are to some extent capable of amoeboid movements. Specimens observed in preparations measure on the average 8 μ × 12 μ, 8 μ × 13.3 μ being the dimensions of a large specimen, 7 μ × 8 μ those of one of minimum size. The nucleus is in all cases nearly spherical and about 2.7 μ in diameter; it is highly refractive and stains deeply with haematoxylin. The cytoplasm has a great affinity for eosin, but is not stained by haematoxylin; it has a coarsely granular appearance,

and often contains one or two highly refractive extranuclear chromatic bodies.

The spheruliferous corpuscles, which are found in small numbers among the much more numerous blood corpuscles, are like those which have already been described in the account of the connective-tissue layer of the integument. The brown corpuscles have been mentioned in connection with the wall of the intestine. They are to be regarded as a modification of the colorless corpuscles, and their color is probably due to waste products contained in them.

It seems probable that the irregular non-living mass of brown spherules which sometimes nearly fills the lumen of the Polian vesicle is derived from the brown wandering cells. I regard it as an excretory product. The fact that the brown cells are found in a living condition in the Polian vesicle and the close resemblance in the size of the spherules of the living cell to those of the dead mass lead one, in the absence of any other probable explanation, to regard the latter as being derived from the brown amoeboid cells. The spherules of the dead mass have no affinity for eosin or carmine, and only an occasional one is stained by haematoxylin.[1]

3. CIRCULATION OF FLUIDS IN THE TENTACLES.

If a small specimen of Caudina is thoroughly stupefied and observed alive in sea water under a low power of the compound microscope (Zeiss, obj. A., oc. 3), the course of the water-vascular fluids in the tentacles can be readily followed by means of the numerous red blood corpuscles. The stream runs anteriad along the axial side of the tentacle, probably from the radial canal, until it is divided into two streams, which run side by side, first into the *axial* finger-like processes of the tentacles and thence into the two peripheral processes (Plate **6**, fig. 78); the two currents then unite and flow posteriad, probably into the ampulla and thence, it is probable, into the abaxial side of the radial vessel. The circulation is thus a sort of rotation, which reminds one of the protoplasmic movements in Nitella; each stream flows quite to the tip of the *axial* process, which generally points directly anteriad, turns sharply upon itself, and runs into the abaxial process, which is curved outward in such a way that the stream meets with the least possible resistance; here again the

[1] Such a mass of brownish spherules I have found at the extremity of an ovarian tubule of Thyone and similar spherules in the body cavity of Caudina.

stream flows to the tip of the process and turns upon itself to run backward into the ampulla. When aëration becomes poor, the tentacles and buccal region become distended with the water-vascular fluids, and the posterior part of the body becomes pale and contracted; it is probable that at such a time the tentacular valves close, and that circulation is confined to the tentacle and the ampulla connected with it.

10. SYSTEM OF HAEMAL LACUNAE.

In Caudina this system closely resembles that of the Cucumariidae, as described by Hamann and Hérouard. It may be considered as consisting of four parts: (1) a diffuse ring immediately behind the circular canal of the water-vascular system, (2) intestinal vessels, (3) lacunae of the reproductive organs, and (4) radial and tentacular vessels.

The *circular lacunae* which form the center of the system, occupy the connective tissue of the wall of the stomach immediately behind the circular canal of the water-vascular system. Arising from the external layer of connective tissue of the stomach are extensive outgrowths of the same tissue covered with peritoneal epithelium; these contain the sinuses which constitute the circular haemal vessel. The walls of the sinuses are connected by narrow stalks with the connective-tissue layer of the stomach, and distally are united into a nearly continuous sheath around the stomach.

The ventral or antimesenterial *intestinal vessel* is shown at *va. sng.* in Plate **4**, fig. 46. Several cross branches connect the two parts of this vessel which run along the descending and ascending portions of the small intestine. At the bend between the small and large intestines there is a delicate sheet of anastomosing vessels. The two parts of the dorsal intestinal vessel are likewise connected by anastomosing cross vessels.

The mesenterial vessels possess a wall composed of peritoneal epithelium, continuous with that of the intestine, and beneath this muscle fibers, which run longitudinally, the interior being filled with loose strands and cells of connective tissue belonging to the deep connective-tissue layer of the intestine. The contents, as observed in fresh and living material, consist of a colorless plasma, in which

are blood corpuscles and spheruliferous wandering cells, the latter being extremely rare as compared with the former.

The *lacunae of the reproductive organs* appear in the genital tubules as internal longitudinal projections of the wall, involving the connective-tissue layer and covered with a single layer of flat epithelial cells (Plate **6**, fig. 83).

Radial and *tentacular lacunae.* The five radial ambulacral vessels, as they run forward from the circular water tube, are accompanied by lacunae in the connective tissue of their inner or axial walls (*sng. r.*, Plate **5**, figs. 69–72). These lacunae, accompanying the radial vessels of the water-vascular system forward on the axial side of the radial plates of the calcareous ring, branch with them and accompany the branches as far as the tentacles and thence for a considerable distance the walls of the tentacles themselves. From the region of the branches to the tentacles, each radial lacuna can be followed backward along the entire length of a radial vessel of the water-vascular system; it lies in the body-wall between the loose fibers composing the connective-tissue partition which separates the hyponeural canal from the radial water canal (Plate **3**, fig. 40, *sng. r.*). At the tip of the tail these radial lacunae communicate with a circular lacuna, which surrounds the anal opening.

The contents of the radial lacunae and of the lacunae of the reproductive organs are a homogeneous plasma, staining well with eosin. In this plasma are occasionally found spheruliferous wandering cells. Blood corpuscles, which in the intestinal vessels are far more numerous than the spheruliferous cells, are never found in the other parts of the lacunar system.

11. REPRODUCTIVE ORGANS.

1. ANATOMY.

The sexual organs of Caudina arenata consist of two bunches of dichotomously branching tubules of almost uniform caliber, suspended, one on either side of the dorsal mesentery, at the point where they unite to open into a common genital duct. The left bunch is slightly larger than the right. It is well known, that, when only one bunch of genital tubules is developed, as in many of the Holothuriidae and

in a considerable number of the Elpidiidae, it is always the left; it would appear that the cause which has produced such a condition in these forms is the same as that acting to produce the inequality in Caudina. Ludwig ('81) has found, however, that in Chirodota rotifera the right group of tubules is the more fully developed, and the same appears to be true of Ankyroderma Jeffreysii, as figured by Danielssen and Koren ('82, Tab. 10, fig. 15); so that, whatever the cause of this inequality in right and left sides, the conditions in different holothurians, even though they are closely related forms, are unlike. When fully developed the genital tubules fill the larger part of the body cavity, extending backward to the base of the respiratory trees. A single tubule with its branches has been figured by Semper ('68, Taf. 10, fig. 12), and by Kingsley ('81, Plate 2, fig. 13).

The genital duct (*dt. gen.*), which is about 2 cm. long in a full-grown individual, runs forward between the two layers of the mesentery (Plate **4**, fig. 46; Plate **5**, fig. 66) and opens to the exterior through a single orifice in the conical papilla of the integument (*pa. gen.*), which has been described in connection with the external features of the animal. In the sexually mature male (Plate **4**, fig. 46) it is not of uniform size throughout, its posterior half being distended into a spindle-shaped enlargement 2 mm. in diameter, while the anterior half is reduced to a diameter of about 0.5 mm. Although there are no external differences in the appearance of the male and female individuals, the color of the reproductive organs enables one at a glance to distinguish them; the testes are uniformly of a light yellow color, whereas the ovaries are pale brown. The color is due entirely to the contents of the tubules, the walls of which are somewhat translucent and not pigmented. I have arrived at these conclusions after examining scores of living and freshly killed individuals and after studying by means of sections the sexual organs of a large number of specimens.

While the sexes have hitherto been shown to be separate in all the Molpadiidae except Caudina, there has been some doubt in regard to the conditions in this genus. Semper ('68) asserts that Caudina is hermaphroditic, and figures a cross section of a sexual tubule showing ova and masses of granular matter, nearly filling the lumen of the tubules, which he believed to consist of sperm cells. This matter was undoubtedly derived from the coagulum that fills the genital lacunae. Kingsley ('81), on the contrary, makes the statement, though without producing any evidence to corroborate it, that in

Caudina the sexes are separate. Since it is now shown that Caudina is a dioecious form, it may be stated with confidence that in the family Molpadiidae, as far as known, the sexes are without exception separate.

2. HISTOLOGY.

The walls of the genital tubules in both sexes consist of four layers of cells: (*a*) peritoneal epithelium, (*b*) *circular* muscle fibers, (*c*) connective tissue, and (*d*) the internal, germinal epithelium.

a. The *peritoneal epithelium* consists of flat, ciliated cells with polygonal outlines (Plate **6**, figs. 81, 82). .The diameter of the cells is about 3 μ, that of the nuclei about 1 μ.

In two forms of Cucumariidae which I have examined, Thyone briareus and Cucumaria frondosa, this external layer consists of peculiar club-shaped cells, such as Jourdan ('83) has described in connection with the testes of Cucumaria tergestina and the genital tubules of Phyllophorus, and likewise similar to those in Colochirus Lacazii as described by Hérouard ('89). Jensen ('83) has also described them in Cucumaria. It is probable that this club-shaped type of peritoneal epithelial cell is characteristic of the genital tubules of the Cucumariidae. The walls of the testes and ovaries in Thyone are, as I have found, ciliated.

There are no muscle fibers differentiated from the peritoneal epithelial cells of the genital tubules in Caudina. In this respect Caudina differs from Holothuria tubulosa, where Hamann has described muscle processes running longitudinally.

b. The only *musculature* of the genital tubules consists of long, slender, unbranched fibers (Plate **6**, fig. 84), circular in cross section and tapering very gradually toward either extremity. They run around the tubule (Fig. 83) in planes perpendicular to its length; longitudinal muscle fibers are found only in the genital duct. The nucleus is situated upon the side of the fiber about half way between its two extremities. The length of the fibers is so great that in the genital tubules of full-grown individuals they pass nearly or quite around the tubule. The one figured (Fig. 84) is of about the average size, 0.7 mm. long and 4 or 5 μ in thickness. They are so abundant as to form a nearly continuous layer immediately beneath

the peritoneal epithelium. In view of the widely differing results in the observations of various investigators upon this muscle layer,— they have been reviewed by Ludwig ('89–'92, p. 191), — it may be well to add that in Thyone, as in Caudina, I have found only circular fibers, whereas in Synapta Girardii Pourtalès there is a layer of longitudinal fibers, beneath which occasional circular fibers occur, that are by no means numerous enough to form a distinct layer. My observations upon Caudina and Thyone agree with those of Jourdan upon Cucumaria and Phyllophorus, as well as with those of Hérouard; the species of Synapta which I have examined differs from S. digitata, as described by Hamann, in that it lacks a continuous layer of circular muscle fibers.

c. The *connective-tissue* layer consists of closely laid fibers and stellate cells. The most of the fibers run in a longitudinal direction, and form in some cases a close but extremely thin weft, immediately beneath the muscle layer. It is in the spaces between the fibers of connective tissue that the homogeneous blood plasma circulates. Upon opening a tubule one finds longitudinal folds of tissue (*lac. oa.*) extending into the lumen (Plate **6**, fig. 83). There are often two of these in the same part of the tubule, but on opposite sides; or there may be in some tubules several nearly parallel folds projecting from the inner wall. This loose tissue forms a part of the lacunar system, and in its interstices there is contained a homogeneous blood plasm. Flat cells of the internal epithelial layer enclose these haemal sinuses, and scattered stellate cells stretch across the lacunae. No calcareous bodies are to be found in this connective-tissue layer.

d. The *internal epithelium* requires a more extended account than has been given of the other layers. I shall describe first the conditions in the female and then those in the male.

Ovaries and oögenesis. In the youngest individuals which I have succeeded in obtaining, the tubules of both sexes were just beginning to branch. At this stage of development the cells of the germinal epithelium are attached in irregular masses to the inner wall of the egg tubules. These masses have probably resulted from the division of the primitive sexual cells. Already the future ova are to be distinguished by their larger size from the cells destined to form around them a follicle (Plate **6**, fig. 83). The two kinds of cells resemble each other in having relatively large spherical, or slightly oval, nuclei, containing numerous small chromatic bodies

(nucleoli) lying close against the nuclear membrane; but the nuclei of the future ova are many times larger than those of the follicular cells. The cells are all irregularly polyhedral, owing to mutual pressure. The cytoplasm at this stage is homogeneous, the nucleus finely granular.

The cells which are to form the follicle gradually lose cytoplasm and flatten out against the ovum (Plate **6**, figs. 87–91). Eventually the nucleus itself becomes flattened, and the cell body transparent. The boundaries of the cells in the well-developed follicle, as made out with silver nitrate (Plate **6**, fig. 85), are sinuous. Whether the sinuosity of the cell outline is here due to a contracted condition of the underlying tissue, as Muscatello ('94) found to be the case with endothelium of vertebrates, I have not had an opportunity to decide by experiment. The cells have a greater diameter than that of any other epithelial cells in Caudina.

As the incipient ova grow, the chromatic bodies of their nuclei (the nucleoli) increase in size, and a network of less deeply staining substance makes its appearance in the nucleus (Plate **6**, figs. 87–91, 86). Meanwhile the cytoplasm, hitherto homogeneous, becomes differentiated into a peripheral, deeply staining layer and a central, circumnuclear portion, which takes the stain less deeply (Figs. 86, 89, 91). The two layers are from the beginning separated by a membranous protoplasmic structure, *intravitelline membrane*, which under a high power presents in sections a broken outline; from this fact it may be inferred that the membrane is probably a network, not a continuous sheet.

At an early stage in the growth of the immature ovum, even before a definite follicle is formed, this membranous structure is found to be attached to the periphery of the ovum on the side next the lumen of the tubule (Figs. 86, 88, 89), being thus drawn out, as it were, into a funnel-shaped prolongation or neck. At this point the micropyle is subsequently formed. It is probable that this funnel-shaped portion of the membrane becomes perforated at its apex and that the lips of the perforation become continuous with the adjacent cells upon the surface of the ovum, which are becoming flattened and are presently to form the follicle.

When the ovum has attained a diameter of perhaps 80–124 μ with a germinative vesicle of 44 μ by 53 μ, a *zona radiata* begins to be secreted between the yolk and the follicle. This is interrupted at only one point, the place where the funnel-shaped membrane comes

to the surface and joins the follicle. Here there is a conical, or sometimes hour-glass shaped, passage through the whole thickness of the zona, which is sometimes drawn out into a sort of chimney-like elevation around the orifice (Plate **7**, figs. 94, 95).

The zona when fully developed is about 4 μ thick, in eggs which have been sectioned, but in fresh ova it becomes by the absorption of water 20–30 μ in thickness. Like the zona radiata generally, it is transparent, colorless, and marked with radiating lines; it is not stainable with carmine, but takes haematoxylin and methyl green readily, so that it can be easily distinguished from the follicle. By macerating a well-grown ovum the zona is found to consist, not of a homogeneous substance pierced with pore canals,—as Hamann believes is the case in Holothuria tubulosa,— but of an inner transparent, homogeneous yolk membrane, which makes up about a third of the thickness of the zona, and of an outer layer composed in the main of highly refractive and elastic rods, which can easily be separated from one another, but which adhere closely to the yolk membrane (Plate **7**, fig. 96). Semper may have recognized this fact, for, in figuring the zona of the egg of Caudina (Taf. 10, fig. 8), he shows two layers of nearly equal thickness; and he calls the outer the "*faserige Schicht.*" In the text, however, he states that the *Eihaut* as a whole is pierced with numerous pore canals.

Is the zona radiata secreted by the ovum or by the follicular cells? Semper in discussing this question suggests that in general the follicular cells, at the time that the zona first appears, are so far modified as to have probably ceased to be actively metabolic, but he adds that in Caudina arenata it seems probable that a part, if not all, of the *Eihaut* is the product of the follicular cells. He does not state, however, on what he bases this conclusion.

Examination of sections shows clearly that at the time when the zona radiata begins to appear the follicular cells are already very much modified, being flattened into a thin transparent membrane, while the nuclei, which alone can be considered to be actively metabolic, are widely scattered. Furthermore, the fact that, just before a definite zona can be said to be present, the cortical portion of the yolk stains more deeply than the rest of it, seems to indicate that the secretion of the zona by the ovum is already in preparation.

There is reason for believing that only the outer or cortical layer of the egg cytoplasm is concerned in the secretion of the zona, because at the point where the intravitelline membrane comes to the surface,

the inner layer of yolk substance, which reaches up into the funnel-shaped neck of the membrane, secretes nothing resembling a zona radiata, but leaves on the contrary a passage through that envelope. Finally, it is evident in the well-grown ovum that the zona is far more closely connected with the egg cytoplasm than with the follicle (Plate **7**, fig. 96). Its radiating fibers must be regarded, in fact, as processes which have arisen by secretion from the surface of the egg cytoplasm.

The peculiar membrane within the ovum, which is joined to the follicular epithelium on one side of the egg by a funnel-shaped prolongation, will now be described in greater detail. In the full-grown ovum (Plate **6**, fig. 93; Plate **7**, figs. 94–100) the intravitelline membrane consists of two parts: (1) an outer, short, tubular, portion and (2) an inner, very delicate, flaring portion. The former is connected externally with the follicle, from which it passes radially inward through an orifice in the zona radiata known as the micropyle, and thence inward into the yolk for a greater or less distance. The inner part is continuous with the outer, and in its further course surrounds the nucleus at a greater or less distance, probably on all sides. The presence of the inner part of the membrane can be demonstrated by treating fresh ova with one per cent acetic acid (Plate **7**, fig. 99), or by artificially displacing the germinative vesicle (Fig. 100). Sometimes, also, in sections certain radiations extending inwardly from the micropyle toward the nucleus indicate its presence (Plate **6**, fig. 93).

This membrane likewise exists in relation with a micropyle in the ovarian eggs of Cucumaria frondosa, sections of which sometimes afford a good idea of its appearance (Plate **8**, fig. 101). Semper's ('68) figures of the ovum of Holothuria immobilis (Taf. 36, fig. 7) and Hérouard's of H. catensis (Planche 30, fig. 12) probably show the presence of this membrane in the Holothuriidae, although it is nowhere referred to in the text of either author.

To sum up what has been said in regard to the nature and origin of the micropylar apparatus in Caudina and in Cucumaria, it may be stated, that it is more complicated than hitherto supposed, being intimately associated with a peculiar membrane, which makes its appearance in the yolk long before the formation of the zona radiata. Since the connection of this intravitelline membrane with the follicular cells is established before the formation of the zona begins, it

follows that the position of the micropyle is determined by the point at which the membrane becomes attached. This membrane is the same as that which, during the early stages in the growth of the egg, separates a circumnuclear, slightly stainable layer of the yolk from a more deeply stainable peripheral layer of it, and soon becomes attached to the periphery of the ovum.

A membrane somewhat similar to that in Caudina has been described by Shäfer ('80) in the ovum of the rabbit and by Van Bambeke ('83) in the eggs of certain bony fishes (Leuciscus, Lota). But in Leuciscus, as well as in the rabbit, the peripheral end of the pocket formed by the membrane is occupied by a yolk nucleus, and it is improbable that the membrane described by these observers has any connection with the micropyle.

The micropyle of the ovum of Caudina has a striking superficial resemblance to the striated appendage of the ova of Sagartia and other actinians, as described by O. und R. Hertwig ('79), which extends from the ovum— which lies imbedded in subepithelial connective tissue—through the entodermal epithelium of the septum to the surface next the gastro-vascular cavity. But no connection between the nucleus and the periphery was observed in this case; besides, the appendage in question is a solid structure, not a tubule. These authors regard the structure as an organ connected with the absorption of nutriment from the fluids of the gastro-vascular cavity. But it would seem unnecessary to attribute to it this function, since the surrounding epithelial cells contribute largely to the nourishment of the ovum. May it not be, primarily at any rate, concerned with the fertilization of the ovum?

The egg stalk of mussels, such as von Jhering ('77) has described in Scrobicularia, resembles the striated appendage of the ovum of Sagartia, in that it is a solid protuberance of cytoplasmic material. In this case, however, the appendage is a means of attachment of the ovum to the wall of the ovary and, as von Jhering has shown, it determines the position of the future micropyle. But in neither actinians nor mussels is the egg appendage to be regarded as the homologue of the membranous funnel in the ovum of Caudina.

Two attempts have been made to explain the method of formation of the micropyle in holothurians. The first is the theory of Johannes Müller ('54[b]), who supposed this to be the point at which the egg is attached by a sort of stalk to the ovarian wall, as in ophiurans. This view was also held by Leydig ('54), who re-

garded the micropyle as the stalk for the attachment of the egg. The observations of Kölliker ('58), which have been confirmed repeatedly by more recent investigators, made it necessary, however, to look for another explanation of the origin of this structure in holothurians, for he showed that the micropyle is situated at the pole of the egg opposite that at which the earlier observers had supposed it to be, viz., on the side next the lumen of the tubule.

The other theory in regard to the origin of the micropyle was proposed by Semper ('68), who maintained that cells of the internal epithelium, constituting at first a single layer, retain throughout oögenesis their intimate connection with one another, constituting a single sheet. One of these cells, the fundament of an ovum, increases rapidly in size and lifts with it, as Semper supposes, a portion of the sheet of epithelium, which thus finally enwraps the growing ovum and becomes the follicle. By a constriction of the basal part of this elevation in the primitive sheet of cells, a sort of stalk is formed attaching the ovum to the ovarian wall; but the micropyle is established at the point directly opposite the stalk, where the ovum is supposed to retain its primitive connection with the original sheet of epithelial cells, a part of which has now become the follicle. Inasmuch, however, as the internal ovarian epithelium in Caudina does not, at the time when the future ova become differentiated, form a continuous sheet consisting of a single layer of cells, Semper's hypothesis is entirely without foundation.

An interesting abnormal condition is shown in Plate **7**, fig. 98, which is a surface view of a well-grown ovarian ovum with four micropyles. The zona radiata was much swollen, from having remained for twenty hours in an aqueous stain. The eggs of the lot from which this specimen was taken possessed quite uniformly four micropylar structures, never more, though in some cases less than that number.

After the formation of the follicle and zona radiata and the establishment of the micropyle, the ovum continues to grow by assimilation of nutriment derived from the homogeneous blood fluid in the longitudinal lacunae, which fill the lumen of the tubule and come into close contact with the ova. The nucleoli, the greater number of which are in contact with the nuclear membrane,

increase in size partly in consequence of the enlargement of a central vacuole in each. Other chromatic bodies, which in the younger ova occupy a central position in the nucleus, either migrate out to the nuclear membrane or, as is more probable, break up into small masses of chromatin, for in the full-grown ovum there are no central nucleoli, but there are a small number of highly vacuolated chromatic bodies in contact with the nuclear membrane. Sections of the ova of Cucumaria frondosa enable me to confirm in detail Jensen's ('83) observations upon the vacuolated condition of the nucleoli of this species.

Yolk nuclei, such as have been described by Van Bambeke ('83), Blochmann ('84 and '86), Henneguy ('93), Jatta ('82), Schütz ('82), Stuhlmann ('86 and '87), and others, make their appearance in the cytoplasm during the growth of the ovum (Plate **7**, figs. 95, 97). They are spheroidal, somewhat less deeply stainable than nucleoli, and each is usually enclosed within a clear space in the cytoplasm.

During the period in which the ova are growing rapidly, especially during the months of October and November, a small number of degenerating eggs are found in nearly every series of sections through the ovaries. They occur in material which is in all respects well preserved. The cells which degenerate at this time are smaller and less mature than many of the ova in the tubules, some of which have a well-developed follicle and zona radiata, the degenerating ova having neither of these envelopes.

They consist of rounded masses of yolk of various sizes (Plate **8**, fig. 102), within some of which traces of a nucleus are found. Although these degenerating cells are not abundant, they possibly contribute to some extent to the support of the growing ova. It is probable that the substance of the degenerating cells is absorbed directly into the blood plasm of the internal lacunae of the ovary.

Testes and spermatogenesis. The sexual cells in the testes of Caudina are extremely unfavorable for study on account of their small size; I have therefore given comparatively little attention to this part of the subject.

In cross sections of the genital tubules of a young male (Plate **8**, figs. 106, 107) in which no fully developed spermatozoa are present, germ cells of three distinct sizes are present. The largest of these, the spermatogonia (*sp'go.*) are found lying against the inner surface of the wall. The average dimensions of these cells are about 8 μ $\times$

12 μ, the large oval nucleus measuring 4 μ × 6 μ. The nuclei show indications of a chromatic network with minute chromatic bodies situated near the periphery of the nucleus and at the points of junction of the threads. Each of these cells probably divides twice, as shown by Field ('93) in other echinoderms.

The smaller cells (Fig. 106), which are to be regarded as spermatocytes (*sp'cy.*), have a spherical nucleus and very little cytoplasm. The nucleus has in sections a diameter of about 4 μ. Under certain conditions the nuclei of these cells stain diffusely, whereas in the nuclei of spermatogonia from the same tubule only the nuclear membrane, the network of nucleoplasm, and the chromatic bodies are stained.

The still smaller cells in the same tubule, which are to be regarded as spermatids (*sp'd.*), also stain diffusely (in Czokor's cochineal). The mature spermatozoön is about 60 μ in length; its head (examined in a fresh condition in sea-water) is about 3.6 μ in diameter.

I have not detected signs of karyokinesis in the germ-cells in any of the testes which I have examined. The specimens were taken from October to February, inclusive. Nor have I found any cell division going on in the ovaries, which were taken at short intervals between the middle of October and the middle of April. It seems highly probable, therefore, that the summer months are the period during which the germinative epithelium of both testes and ovaries is in a state of active cell division.

The spermatozoa are mature during the months of February, March, and April, and perhaps for a longer time. During these months I have several times observed the emission of sperm by specimens which I was keeping alive in an aquarium. The females, which I was able to keep three or four weeks at a time during the winter and early spring, unfortunately never laid eggs while in captivity, nor have I succeeded in fertilizing artificially ova taken from the ovaries.

Genital duct. The wall of the genital duct (Plate **8**, fig. 105) consists of (*a*) an external layer of epithelium composed of flat, ciliated cells, (*b*) a thick layer of fibrous connective tissue, (*c*) longitudinal muscle fibers, which lie in the midst of the connective-tissue layer, and (*d*) an internal epithelium consisting of columnar or spindle-shaped collared cells.

In the proximal extremities of the genital tubules, *i. e.*, in the region where each unites with the genital duct (Plate **8**, fig. 103),

the same histological conditions obtain as in the genital duct, save that the longitudinal muscle fibers of the latter are there replaced by a layer of circular muscle fibers, which are external to the connective-tissue layer and continuous with the layer of circular muscle fibers surrounding the rest of the genital tubules.

Circular muscle fibers forming a sphincter are found in the connective tissue of the terminal part of the duct which passes through the genital papilla. This portion of the duct is separated from the body wall by diverticula of the body cavity, and the connective tissue at the tip of the papilla, where the wall of the duct is continuous with the body-wall, forms an exceedingly thin layer.

The peritoneal epithelium covering the genital duct presents no peculiar conditions; it is like that of the genital tubules.

According to Hamann ('84) muscle fibers are lacking in the genital duct of Synapta digitata and ('83) Cucumaria cucumis. In C. frondosa, I find, however, numerous longitudinal muscle fibers. The conditions in Trochostoma Thomsonii, as described by Danielssen and Koren ('82), appear to be somewhat similar to those in Caudina, since these observers describe a muscle layer intervening between two layers of connective tissue, — the direction of the fibers is, however, not stated.

The oval nucleus of each of the columnar or spindle-shaped epithelial cells lining the duct is situated near the free end of the cell (Figs. 104 and 105). The cells gradually diminish in diameter from the region of the nucleus to their bases, which terminate in the connective-tissue wall of the duct; at the other or inner end the cell body tapers more rapidly from the region of the nucleus, and terminates in a long flagellum; the tapering free end of the cell body and the base of the flagellum are enclosed within a collar-shaped prolongation, which arises immediately beyond the nucleus, on the side next the lumen of the duct (Fig. 108).

12. PHYLOGENY.

A result of the study which I have made of the structure of Caudina arenata and other holothurians has been to strengthen in my mind the conviction that the Molpadiidae are more closely related to the Cucumariidae than to any other family. The prin-

cipal reasons which lead to this conclusion have been presented in a masterly way by Ludwig ('91[a], p. 492–495 and Bronn's Thierreich, Bd. 2, Abth. 3, p. 448–451). It is therefore necessary in this connection to bring up only a few points in regard to Caudina, hitherto somewhat unsettled, which may bear upon the relationships of the Molpadiidae.

In the first place I have found that there are invariably fifteen tentacles, the normal number for the Molpadiidae. This number, as Ludwig has suggested, has never been found in the Holothuriidae, whereas it occurs in both the Cucumariidae and the Synaptidae. The similarity in the arrangement of the muscle layers in the wall of the alimentary canal of Caudina and of Cucumaria, in distinction from the conditions in Holothuria tubulosa, has already been noted (p. 34, 35), and the same has been shown by Danielssen and Koren for another representative of the Molpadiidae, Trochostoma Thomsonii. Finally the arrangement of tentacles in the interradii in Caudina resembles that found in the Cucumariidae rather than the conditions which obtain in the Holothuriidae.

So marked are the differences which distinguish the Cucumariidae and Molpadiidae from the Holothuriidae, that Ludwig concludes that they together represent one of the two diverging branches of the Holothurioidea. The Synaptidae, he believes, are derived from the former branch before its divarication to form the Molpadiidae and Cucumariidae. The Synaptidae are distinguished from all other holothurians (1) by having uninterrupted circular muscles in the body-wall, (2) by the structure of the calcareous ring, (3) by the absence of radial canals, (4) by the presence, in some cases, of an external longitudinal muscle layer throughout the wall of the alimentary canal, (5) by the absence of respiratory trees and the presence of ciliated urns, and, finally, as I am now able to add with a reasonable degree of certainty, (6) by the fact, that in this family are found the only hermaphrodites which occur among holothurians. Inasmuch as the Synaptidae differ in so many points from other holothurians, the idea advanced by Cuénot and others, that they have been derived from a primitive form distinct from the ancestors of the remaining families, seems not wholly improbable. I am, however, inclined to adopt the view of Ludwig, that they represent an early off-shoot from the common branch of the Cucumariidae and Molpadiidae near its junction with the main stem from which all holothurians have arisen. The many points of similarity both in gross

anatomy and histology between the Synaptidae and other holothurians seem to indicate that both had a common ancestry.

The water-vascular system both in the Molpadiidae and Synaptidae has undergone a marked degeneration in adaptation to a life of burrowing in the sand; in the former the radial canals and a few rudimentary ambulacra only remain; in the latter even the radial canals, as Ludwig has shown, are lost during the development of the individual.

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LITERATURE IN WHICH CAUDINA ARENATA IS DESCRIBED OR MENTIONED.

(Arranged chronologically.)

Chirodota arenata.

1. Gould, A. A. ('41)[1], p. 346 (with woodcut).
2. Pourtalès, L. F. ('51), p. 13, 14.
3. Stimpson, W. ('51), p. 67. (A note as to habitat.)
4. Ayres, W. O. ('52), p. 143–145.

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5. Stimpson, W. ('53), p. 17.
6. Agassiz, E. C. and A. ('65), p. 97, Fig. 126.
7. Clark, H. J. ('65), p. 187–193, Figs. 114–116.
8. Verrill, A. E. ('66), p. 354.
9. Selenka, E. ('67), p. 358–359, Taf. 20, Figs. 129–131.
10. Semper, C. ('68), p. 44, Taf. 10, Figs. 8, 12, 14; Taf. 13, Fig. 5; Taf. 15, Fig. 18.
11. Teuscher, R. ('76), p. 542–560, Taf. 22.
12. Kingsley, J. S. ('81), p. 1–14, Pls. 1, 2.
13. Marenzeller, E. von. ('81), p. 126, 127.
14. Ludwig, H. ('82), p. 129. (A notice of eight specimens from Grand Manan.)
15. Théel, H. ('82), p. 54.

Caudina arenata armata.

16. Théel, H. ('86b), p. 17, 18.

[1] See preceding Bibliography.

EXPLANATION OF PLATES.

All the figures except 46, 67, 78, and 80 were made with the aid of a camera lucida, and all except 34–37, 53, 86, and 101 are from *Caudina arenata* Gould.

Figures 34–37 are from *C. arenata* var. *armata* Théel.

Figures 53, 86, and 101 are from *Cucumaria frondosa*.

Abbreviations.

amp.	Ampulla of tentacle.
ann. n	Nerve ring.
aq. crc.	Circular water canal.
aq. r.	Radial water canal.
aq. r.'	Median-ventral radial water canal.
aq. ta.	Tentacular branch of radial water canal.
aq. ta.'	Tentacular branch of radial water canal to median-ventral tentacle.
can. lap.	Stone canal.
clc.	Cloaca.
cl. fol.	Follicular cell.
cl. gn.	Ganglionic cell.
cl. sns.	Sensory cell of epithelium.
cl. sst.	Supporting cell of epithelium.
cl. vag.	Wandering cell in pharynx.
cp. sph.	Spheruliferous wandering corpuscle.
cp. sph.'	Spheruliferous corpuscle with finer spherules than *cp. sph.*
cta.	Cuticula.
dt. gen.	Genital duct.
e'n. crc.	Circular epineural canal.
e'n. r.	Radial epineural canal.
en'th.	Endothelium.
e'th.	Epithelium.
e'th. buc.	Epithelium of the buccal region.
e'th. ex.	External epithelium.
e'th. ex. oa.	External epithelium of the ovary.
e'th. i.	Internal epithelium.
fbr. sst.	Supporting fibers of nerve bands.
gl. tbl.	Tubular gland cell.
h'pn. r.	Hyponeural canal.
lac. oa.	Lacunar blood vessel of the ovary.
mad.	Madreporic body.
m'py.	Micropyle.
ms'ent. d.	Dorsal mesentery.
mu.	Muscle fibers.
mu. crc.	Circular muscle fibers.
mu. lg.	Longitudinal muscle fibers.
mu. lg.'	Longitudinal muscles in the wall between *aq. r.* and *h'pn. r.* (Plate 4), and longitudinal muscle fibers of rudimentary ambulacral foot (Plate 6).
mu. lg. ta.	Longitudinal muscles of tentacles.

mu. r. buc. Radial muscles of buccal region.
miu. r. v. Median-ventral radial muscle.
mu. ta. Muscle layer of tentacles
mu. tr. Transverse muscles of the body-wall.
n. Nervous tissue.
n. buc. Buccal nerve.
n. con Conical buccal nerve (abnormality).
nl. Nucleus.
nl ?. Remnant of nucleus in a degenerating ovum.
nl. vt. Yolk nucleus.
n. r. dx-d. Right-dorsal radial nerve.
n. r. ex. External band of the radial nerve.
n. r. i. Internal band of the radial nerve.
n. ta. Nerve to tentacle.
o. rsp. dx. Right branch of respiratory tree.
o. rsp. s-d. Left-dorsal branch of respiratory tree.
o. rsp. s-v. Left-ventral branch of respiratory tree.
pa. an. Anal papilla.
pa. gen. Genital papilla.
par. oa. Wall of the ovary.
sep. Connective-tissue partition.
sng. r. Radial blood sinus.
sng. ta. Tentacular blood sinus.
sp'cy. Spermatocyte.
sp'd. Spermatid.
sp'go. Spermatogonium.
spht. buc. Buccal sphincter.
sul. Furrow upon the surface of the nerve ring.
tbl. mu. Tubules composed of muscle fibers.
tis. con't. Connective tissue.
tis. con't. ex. External layer of connective tissue in wall of respiratory tree.
tis. con't. i. Internal layer of same.
va. sng. Antimesenterial blood vessel of the small intestine.
vs. Pol. Polian vesicle.
vt. ex. External layer of yolk, separated by an intravitelline membrane from
vt. i. Internal layer of yolk.
z. r. Zona radiata.

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mulq

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mu.tr
aq.r
mu.lg
44.
en.crc.
ann.n.
n.ta
eth.buc.
sphtbuc.
mu.lg.
mu.r.buc.
n.buc.
45.
n.con
46.
pa.gen
amp
mad
aq.crc
dt.gen
va.sng
o.rsp.s.v.
o.rsp.dx
o.rsp.s.d
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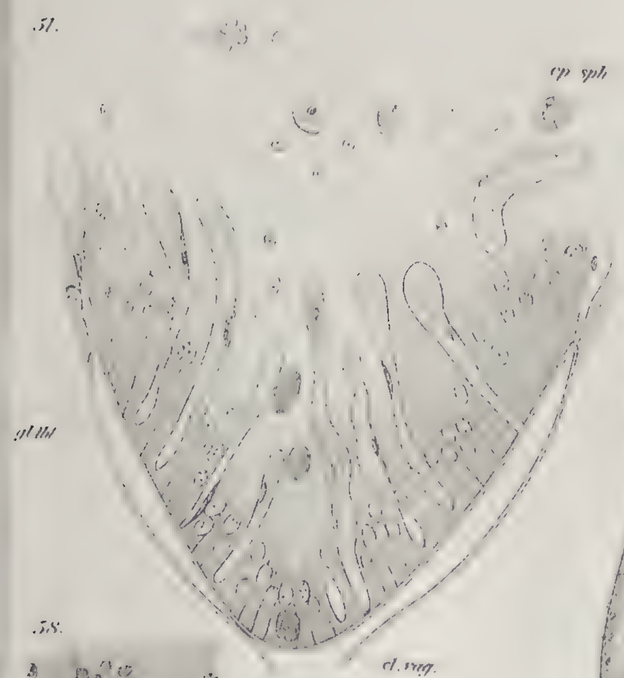

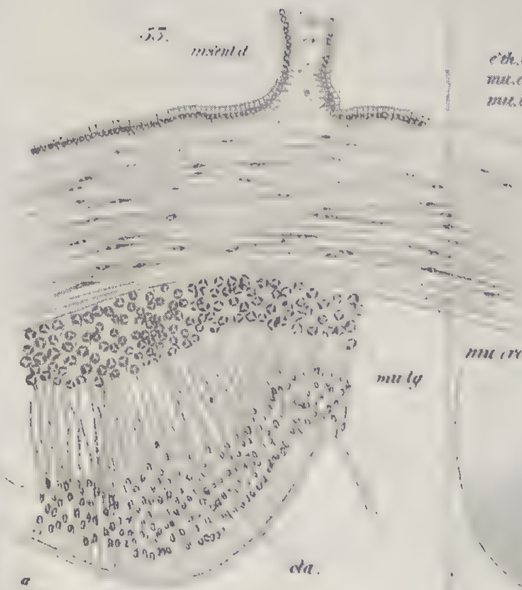

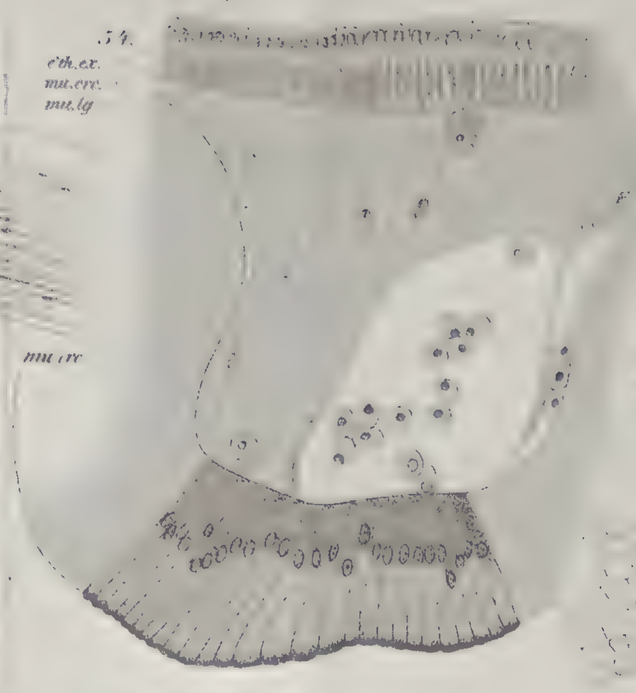

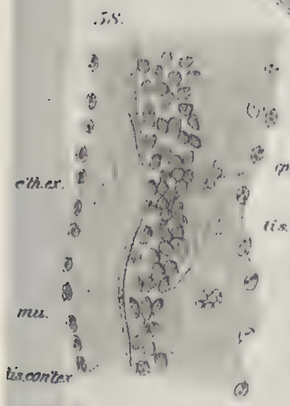

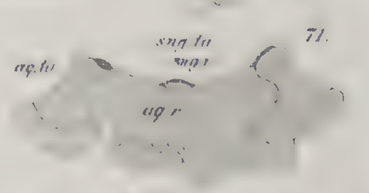

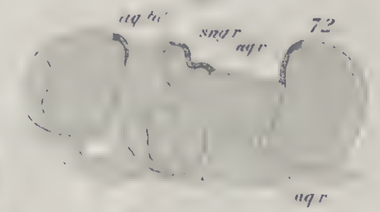

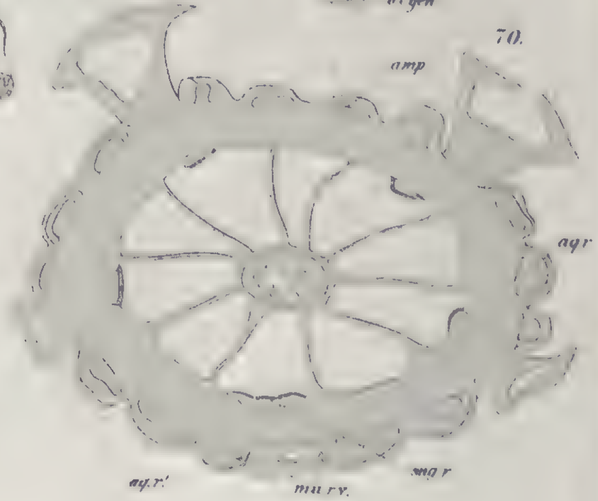

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tis.con't
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91.
eth.ex.oa
m'py
93.
mu.tr
mu.lg'
aq.r.
mu.lg

PLATE 1.

ABBREVIATIONS.

aq. crc.	Circular water canal.
aq. r.	Radial water canal.
cl. gn.	Ganglionic cell.
cp. sph.	Spheruliferous wandering cell.
cta.	Cuticula.
e'n. r.	Radial epineural canal.
en'th.	Endothelium.
e'th.	Epithelium.
h'pn. r.	Hyponeural canal.
mad.	Madreporic body.
mu. tr.	Transverse muscles of the body-wall.
n.	Nervous tissue.
n. r. ex.	External band of the radial nerve.
n. r. i.	Internal band of the radial nerve.
pa. gen.	Genital papilla.
sep.	Connective-tissue partition.
sng. r.	Radial haemal vessel.
tbl. mu.	Tubules composed of muscle fibers.

Fig. 1. Cross section through one of the radial nerves and accompanying vessels. × 360.

Fig. 2. Cross section through the body-wall near the region of the tentacles. × 330.

Fig. 3. Portion of circular water canal with stone canal and madreporic body. × 12.

Fig. 4. Oblique view of anterior extremity of the body. × 6.

Fig. 5. Cross section of the body-wall through a radius, showing muscle tubules. × 118.

PLATE 2.

ABBREVIATIONS.

cl. sns. Sensory cell of epithelium.
cl. sst. Supporting cell of epithelium.
gl. tbl. Tubular gland cell.

Figs. 6–8. Supporting cells from epithelium of tentacles. × 940.
Fig. 9. Sensory cell from epithelium of the tentacles. × 940.
Fig. 10. Tubular gland cell from the tentacles. × 940.
Figs. 11, 11a. Muscle cells from a radial longitudinal muscle band. × 222.
Fig. 12. The same in a state of contraction. × 222.
Fig. 13. One half of a muscle fiber from the pharynx. × 360.
Fig. 14. Middle part of the same. × 700.
Fig. 15. Group of cells seen in a cross section of tentacle. × 940.
Fig. 16. Longitudinal section through the axial side of one of the inner processes of a tentacle. × 490.

6.

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11a

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14.

15.

al int

al ext.

al ext.

16.

al int

PLATE 3.

ABBREVIATIONS.

aq. r.	Radial water canal.	*mu. r. buc.*	Radial muscles of buccal region.
e'n. crc.	Circular epineural canal.		
e'n. r.	Radial epineural canal.	*n. r. ex.*	External band of radial nerve.
en'th.	Endothelium.		
fbr. sst.	Supporting fibers of nerve bands.	*n. r. i.*	Internal band of radial nerve.
h'pn. r.	Radial hyponeural canal.	*n. ta.*	Nerve to tentacle.
mu. crc.	Circular muscle fibers.	*sep.*	Connective-tissue partition.
mu. lg.	Longitudinal muscles of body-wall.	*sng. r.*	Radial blood sinus.
mu. lg. ta.	Longitudinal muscles of tentacles.	*sul.*	Furrow upon the surface of the nerve ring.

Fig. 17. Seven large and four smaller calcareous bodies drawn in their natural position in the integument; seen from without. × 280.

Fig. 18. Calcareous table; side view. × 280.

Fig. 19. Calcareous table; oblique view. × 280.

Fig. 20. Spicule from the superficial layer of the calcareous ring. × 280.

Figs. 21–24. Calcareous rods from the deeper portion of a radial calcareous plate. × 280.

Fig. 25. Spicules from the madreporic body. × 270.

Figs. 26–33. Series illustrating the development of the calcareous tables. × 280.

Fig. 26a. Same as Fig. 26, but enlarged and showing cells adjacent to it. × 460.

Fig. 33. Calcareous table, showing the method of development of the leg.

Figs. 34–36. Calcareous bodies from the integument of *C. arenata armata*. Viewed from their outer surfaces. × 280.

Fig. 37. The same; side view.

Fig. 38. Longitudinal section through the posterior part of the nerve ring. (Comp. Pl. **4**, Fig. 44.)

Fig. 39. Longitudinal section of the nerve ring, showing its anterior furrow and the tendency of ganglion cells to be arranged in lines. × 490.

Fig. 40. Cross section through the radial nerve and accompanying organs. × 280.

Fig. 41. Transverse supporting fibers from a cross section of the nerve ring. × 460.

Fig. 42. Cross section of the nerve ring. × 360.

PLATE 4.

ABBREVIATIONS.

amp.	Ampulla of tentacle.	*mu. tr.*	Transverse interradial muscles.
ann. n.	Nerve ring.		
aq. crc.	Circular water canal.	*n. buc.*	Buccal nerve.
aq. r.	Radial water canal.	*n. con.*	Conical buccal nerve (abnormality).
clc.	Cloaca.		
dt. gen.	Genital duct.	*n. r. dx-d.*	Right-dorsal radial nerve.
e'n. crc.	Circular epineural canal.	*n. r. ex.*	External band of same.
e'n. r.	Radial epineural canal.	*n. r. i.*	Internal band of same.
en'th.	Endothelium.	*n. ta.*	Nerve of tentacle.
e'th. buc.	Epithelium of the buccal region.	*o. rsp. dx.*	Right branch of respiratory tree.
h'pn. r.	Hyponeural canal.	*o. rsp. s-d.*	Left-dorsal branch of respiratory tree.
mad.	Madreporic body.	*o. rsp. s-v.*	Left-ventral branch of respiratory tree.
mu. lg.	Longitudinal radial muscles of body-wall.	*pa. an.*	Anal papilla.
mu. lg.'	Longitudinal muscles in the wall between *aq. r.* and *h'pn. r.*	*pa. gen.*	Genital papilla.
		spht. buc.	Buccal sphincter.
mu. r. buc.	Radial muscles of buccal region.	*va. sng.*	Antimesenterial blood vessel of the small intestine.
mu. ta.	Muscle layer of tentacles.		

Fig. 43. Cross section of the radial nerve, showing distribution of fibers from its inner band. × 270.

Fig. 44. Radial longitudinal section through the buccal region and the wall of the tentacle. × 118.

Fig. 45. Section nearly parallel to the plane of the nerve ring and the right-dorsal radial nerve at its beginning. The section is viewed from behind and shows on the right the origin of the abnormal buccal nerve cone. × 440.

Fig. 46. General anatomy of a specimen opened along the right side of the dorsal interradius. Natural size.

Fig. 47. Section parallel to that shown in Fig. 45, but further forward. This shows the abnormal nerve cone in cross section. × 118.

Fig. 48. Sections parallel to the plane of the nerve ring, showing the origin of a tentacular nerve. × 50.

Fig. 49. Cross section of a buccal nerve trunk close to the axial side of the nerve ring. × 370. Compare Fig. 44.

Fig. 50. Radial longitudinal section showing the posterior termination of the radial nerve, the anal papilla (terminal tentacle of the water-vascular system), etc. × 280.

PLATE 5.

For abbreviations see Explanation of Plates, p. 73.

Fig. 51. Cross section through the pharynx, showing the inner epithelium. × 500.

Fig. 52. Cross section through the stomach showing inner epithelium and connective tissue. × 500.

Fig. 53. Cross section through the stomach of *Cucumaria frondosa*. × 40.

Fig. 54. Longitudinal section through the wall of the small intestine of Caudina. × 500.

Fig. 55. Cell from the inner epithelium of small intestine. Maceration preparation. × 500.

Fig. 56. Peritoneal epithelium from the wall of the stomach. × 280.

Fig. 57. Epithelium from the mesentery of the intestine. Silver-nitrate preparation. × 280.

Fig. 58. Section of the wall of the respiratory tree. × 420.

Fig. 59. Peritoneal epithelium from the respiratory tree. × 280.

Fig. 60. Brown spheruliferous corpuscle from the large intestine. × 500.

Fig. 61. Cross section of large intestine showing external longitudinal muscle bands. × 24.

Fig. 62. Section through the inner epithelium of the cloaca. × 280.

Fig. 63. Connective-tissue cell from the mesentery of the small intestine. × 500.

Fig. 64. Interradial plate of calcareous ring; *a*, external; *b*, internal face.

Fig. 65. Radial plate: *a*, edge view; *b*, exterior view; *c*, viewed from within the calcareous ring.

Fig. 66. Aquapharyngeal bulb seen from the left side. × 2.

Fig. 67. Diagram of the branches of the median-ventral radial water canal to the tentacles. View from *within* the aquapharyngeal bulb. Branches graphically reconstructed from a series of sections.

Fig. 68. Posterior face of a cross section through aquapharyngeal bulb showing the openings of the radial canals into the circular canal.

Fig. 69. Posterior face of a section through the aquapharyngeal bulb, further forward than the last.

Fig. 70. Similar view of a section still further forward, where the radial and interradial plates form a continuous ring.

Fig. 71. Portion of posterior face of a cross section further forward showing the opening of the two lateral branches of the median-ventral canal into the tentacles.

Fig. 72. Portion of posterior face of cross section showing the origin, from the radial canal, of the tentacular canal (*aq. ta.'*) which unites with the adjacent (median-ventral) tentacle. In this case the tentacular branch arises on the *left* side of the radial canal.

PLATE 6.

ABBREVIATIONS.

aq. r.	Radial water canal.	*mu. lg.*	Longitudinal muscle fibers of body-wall.
cl. fol.	Follicular cell.		
e'n. r.	Radial epineural canal.	*mu. lg.'*	Longitudinal muscle fibers of rudimentary ambulacral foot.
e'th. ex.	External epithelium of Polian vesicle.		
e'th. ex. oa.	External epithelium of the ovary.	*mu. tr.*	Transverse muscles of body-wall.
e'th. i.	Internal epithelium	*n.*	Nerve.
hp'n. r.	Hyponeural canal.	*par. oa.*	Wall of the ovary.
lac. oa.	Lacunar blood vessel of the ovary.	*tis. con't.*	Connective tissue.
m'py.	Micropyle.	*vt. ex.*	External layer of yolk.
mu. crc.	Circular muscle fibers.	*vt. i.*	Internal layer of yolk.
		z. r.	Zona radiata.

Fig. 73. Cross section of the stone canal. × 12.

Fig. 74. Section of the madreporic body, nearly perpendicular to its flat surfaces. × 37.

Fig. 75. Longitudinal section through the wall of the Polian vesicle. × 535.

Fig. 76. Cross section through the wall of the circular water canal. × 535.

Fig. 77. Longitudinal section through a tentacular canal and upper part of radial plate, showing the valve of the tentacle. × 280.

Fig. 78. Diagrammatic radial section through a tentacle showing the circulation of fluid in it.

Fig. 79. Cross section through the posterior end of a radial water tube and its lateral vessels (rudimentary ambulacral feet) along the line A B of Fig. 80. × 280.

Fig. 80. Graphic reconstruction of the terminal tentacle (the anal papilla) and the two rudimentary ambulacral feet. Scale $6\frac{2}{3}$ μ to 1 mm., or × 150.

Fig. 81. Peritoneal epithelium from the wall of the ovary. Maceration preparation. × 240.

Fig. 82. The same. Silver-nitrate preparation. × 240.

Fig. 83 Part of a cross section of wall of ovary of a young individual. × 720.

Fig. 84. Muscle fiber from the wall of the ovary. × 205.

Fig. 85. Follicular epithelium. Silver-nitrate. × 240.

Fig. 86. Part of cross section of wall of ovary of *Cucumaria frondosa*. × 240.

Fig. 87. Young ovum. × 235.

Figs. 88, 89. Slightly older stages in the growth of the ovum. × 235.

Fig. 90. Ovum showing deep staining of a superficial layer, preparatory to formation, of a zona radiata. × 235.

Fig. 91. Ovum showing two layers of yolk separated by intravitelline membrane. × 235.

Fig. 92. Surface view of interior of ovary showing a well-grown ovum in position and the micropyle projected on the germinative vesicle. × 226.

Fig. 93. Section of a nearly full-grown ovum. Fol's chromic-osmic-acetic mixture. Ehrlich's haematoxylin and eosin. × 235.

PLATE 7.

ABBREVIATIONS.

lac. oa.	Lacunar blood vessel of ovary.	*nl.*	Nucleus.
		nl. vt.	Yolk nucleus.
m'py.	Micropyle.	*z. r.*	Zona radiata.

Fig. 94. Section of a nearly full-grown ovum. Merkel's fluid. × 235.

Fig. 95. The same. Fol's chromic-osmic-acetic mixture. Biondi's triple stain. × 235.

Fig. 96. Zona radiata. Maceration preparation. × 515.

Fig. 97. Section of a well-grown ovum. Perenyi's fluid. Ehrlich's haematoxylin and eosin. × 235.

Fig. 98. Ovum taken from the ovary March 19, killed with corrosive sublimate and stained 20 hours in alcoholic borax-carmine. Examined in 50 per cent alcohol. Diameter of egg with envelopes 0.4 mm.; exclusive of envelopes 0.26 mm. The micropyles lie in successive horizontal planes in the order **α**, **β**, **γ**, **δ**.

Fig. 99. Optical section of ovum treated with 1 per cent acetic acid and mounted in damar. April. Diameter of egg with envelope, 0.24 mm.; diameter of egg excluding envelope, 0.19 mm.; diameter of nucleus, 0.11 mm. × 230.

Fig. 100. Ovarian egg under pressure. November. Optical section showing displaced nucleus and micropyle.

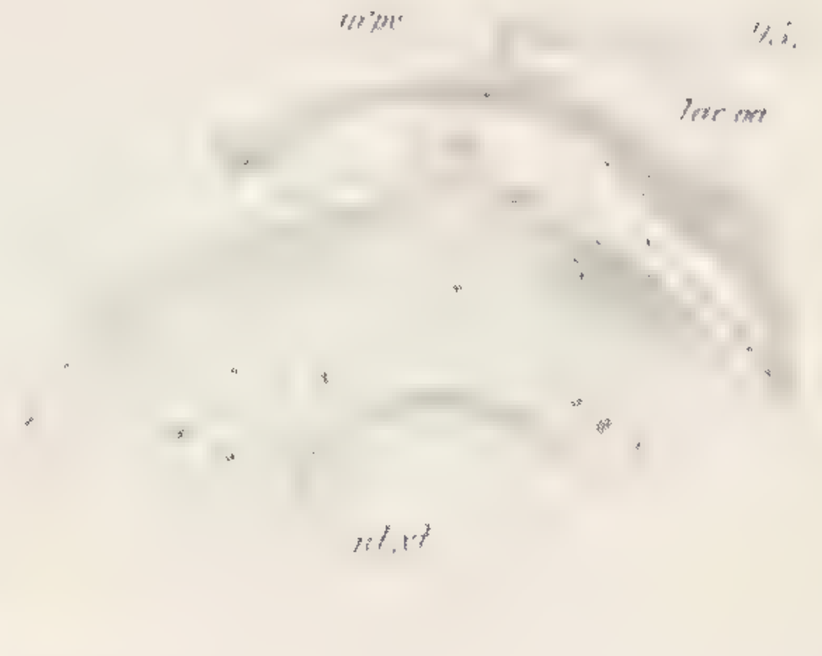

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PLATE 8.

ABBREVIATIONS.

cp. sph.	Spheruliferous corpuscle.	*mu. lg.*	Longitudinal muscle fibers.
e'th. ex.	External epithelium.	*nl.*	Nucleus.
e'th. i.	Internal epithelium.	*nl?.*	Remnant of nucleus in a degenerating ovum.
lac. oa.	Lacunar blood vessel of ovary.	*sp'cy.*	Spermatocyte.
m'py.	Micropyle.	*sp'd.*	Spermatid.
mu. crc.	Circular muscle fibers.	*sp'go.*	Spermatogonium.
		tis. con't.	Connective tissue.

Fig. 101. Section of ovarian ovum of *Cucumaria frondosa*. Picro-sulphuric acid. Ehrlich's haematoxylin and eosin. × 235.

Fig. 102. Ovarian ovum in a state of degeneration. November. Corrosive sublimate. Ehrlich's haematoxylin. × 390.

Fig. 103. Cross section of a *branch* of the genital duct. × 235.

Fig. 104. Internal epithelium of the genital duct from a section of the duct. × 700.

Fig. 105. Longitudinal section of the genital duct. × 514.

Fig. 106. Cross section of the testis of a young individual. × 385.

Fig. 107. Section of wall of testis, showing spermatogonia. × 1125.

Fig. 108. Internal epithelium of genital duct seen in optical section, showing collars surrounding the flagella. × 514.

m'py
101.
nl
102
103.
104.
106
108
sp'd.
sp.cv.
sp'oo
lac.ov

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FURTHER STUDIES ON THE SPERMATOGENESIS OF CALOPTENUS FEMUR-RUBRUM.

BY E. V. WILCOX.

WITH THREE PLATES.

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JUNE, 1896.

No. 4. — *Further Studies on the Spermatogenesis of Caloptenus femur-rubrum.*[1] By E. V. Wilcox.

A continuation of the study of the spermatogenesis of Caloptenus femur-rubum has served to confirm many of the results gained last year (Wilcox, '95), and has made it possible to give a fuller account, particularly of the metamorphosis of the spermatids.

The material for this year's work was collected during the months of August and September. The testes were killed by nearly all the standard methods. Hermann's fluid and Vom Rath's modification of it gave the best results. With my material it is more easy to stain after Vom Rath's than after Hermann's fluid. The spindle fibres and "Nebenkern" are rendered very distinct by Hermann's fluid, no staining being required if the testes are left in this fluid for several hours. I found it unnecessary to use pyroligneous acid to differentiate the various cell structures.

For staining I used Heidenhain's iron-hæmatoxylin with good results. It stains excellently both sections, and *in toto*. Biondi's mixture was used with only moderate success. With low powers there appears to be a very marked differentiation in colors, but the staining is so faint that with high powers it is very difficult and trying for the eye to make out fine details. I tried with good success the modification of Flemming's orange method as given by Reinke ('94, pp. 261–263). The only difficulty I met with was in preventing the gentian violet from being washed out. This last method brings out very clearly a body in the vacuole of the nucleus of the spermatid (Plate **3**, Figs. 94–98).

I will now give a brief account of my own work on the various stages in the development of the male sexual elements, and then a criticism of some recent papers bearing on the subject.

The stage in the division of the spermatogonia which is most common is the dyaster (Plate **1**, Figs. 1, 2). All the spermatogonia in a single compartment are often in almost exactly the same condition (Fig. 2).

[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy at Harvard College, under the direction of E. L. Mark, No. LVIII.

The spermatocytes are represented in Plates **1** and **2**, Figs. 4–47. I have seen no evidence of a longitudinal splitting of the chromatic thread in the prophases of the first division. I still believe that there are two modes of formation of "Vierergruppen" (compare Figs. 4 and 16). The centrosomes are very conspicuous in the best preserved preparations, especially during the first division of the spermatocytes (Plate **1**, Fig. 25). During the second division of the spermatocytes (Figs. 26–35 and 39–45) the centrosomes are not readily distinguished, partly because the chromatic elements are themselves spheroidal and of about the same size as are the centrosomes. The interzonal filaments are very distinct (Plate **2**, Figs. 31–35), particularly after Hermann's killing fluid. There are stainable particles on the fibres, and some of the fibres are thickened for a part of their length (Plate **2**, Figs. 39, 40, 42). Figures 39 and 40 represent equatorial views, and in such cases two or three thickened masses of fibres are seen, which are continuous with ordinary delicate filaments as they approach the chromatin. Ordinary filaments are also to be seen between these thickened strands. An oblique section of such a spindle is represented in Figure 43. Figure 42 is from a cross section. It is to be seen from the last figure that the thickened fibres are arranged in four somewhat unequal groups. In an equatorial view (Figs. 39, 40) one or two groups are obscured by the others.

I have used the term "thickened fibres." As a matter of fact I cannot say that the appearance is not caused by an accumulation of stainable (lanthanin) granules along that portion of the fibres. It is not a simple swelling of the fibres; for in that case they would not become darker, as they are. It is not a massing together of the fibres; for then there would be seen tracts free from fibres, which is not true. Cross sections of the fibres are easily seen, being of considerable size; but they are not to be confounded with the chromosomes, which have a different structure and stain differently. There is in some cases (Fig. 39) a dark granular band across the middle of these thickened strands.

This peculiar condition of the interzonal filaments shown in Figures 39, 40, 42, was found in only a single individual. The testis was killed in Hermann's fluid, the preservation being very good. Many other spermatocytes in the same testis show no thick fibres (compare Fig. 31 with Fig. 40). I am therefore unable to say whether it is an unusual condition, a variation from the ordinary process, or a regular stage which is so quickly passed through that it is only occasionally found.

Spermatids immediately after the second division of the spermatocytes

are shown in Figures 53, 56, 76, and 78. In Figure 78 (Plate **3**) at the upper end of the cell is seen a body which, from its position, stainability, and size, I believe to be the centrosome remaining after the second spermatocyte division. Below it lies the nucleus without as yet a limiting membrane, but containing a deeply stained body within the ring-like group of chromosomes. The remains of the interzonal filaments extend from near the nucleus to the cell membrane opposite the supposed centrosome. At the distal ends of these fibres are some very fine stainable granules.

Let us now consider separately the history of each of these structures, centrosome, nucleus, and interzonal filaments.

The *centrosome* comes ultimately to occupy a position between the nucleus and the modified remains of the interzonal filaments. It apparently moves around the nucleus through an arc of 180 degrees. Figures 78, 80, 79, 81, 82 (Plate **3**) illustrate this migration of the centrosome. I could not find evidence of the division of the centrosome until later stages in metamorphosis, such as those shown in Figures 97–100. The centrosome manifests its double nature with varying degrees of distinctness in the stages last mentioned. Afterwards the two parts fuse into one, and the whole body elongates, as represented in Figures 109 and 110. In subsequent stages the chromatic substance of the head of the immature spermatozoön becomes more compact, and stains so much like the centrosome that it is difficult to mark the limits of the two substances.

The *chromosomes*, as was shown in my previous paper on this subject ('95), soon fuse into a more or less homogeneous mass, which takes on a crescentic shape, leaving in the nucleus at first a rather large vacuole, which is located next to the centrosome or neck-body. One end of the crescent becomes applied to the centrosome, and the whole head elongates, crowding the vacuole to one side. The vacuole finally disappears, and the chromatic substance in consequence of condensation stains more deeply.

The remains of the *interzonal filaments* immediately after the second division of the spermatocyte are shown in Figure 78. We find that at this stage it consists of an elongated striate body composed very evidently of distinct fibres. This oblong fibrous body, which is to become the "Nebenkern," contracts longitudinally, so that the distal ends of the fibres are drawn away from the cell membrane (Figs. 56, 77). The ends of the Nebenkern round themselves off (Fig. 84), and the spermatid soon reaches the stage represented in Fignres 54, 55, 80–83. The

Nebenkern is now seen to be a spheroidal body, in which all traces of a fibrous condition are lost. It lies close by or applied to the nucleus, having the centrosome between it and the nucleus. The Nebenkern now elongates and forms the axial portion of the tail of the spermatozoön (Plate **3**, Figs. 87–89).

From Figures 111–114, which are drawn from a preparation of the testis of Trirhabda tomentosa, one of the Chrysomelidæ, it is readily seen that the relationships and fate of the nucleus, the centrosome, and the Nebenkern are essentially the same as they are in Caloptenus.

The body which appears in the vacuole of the nucleus (Figs. 94–98) is rather problematical, both as to its origin and its fate. It appears usually as a rod of deeply staining substance, whose longest axis is in the long axis of the vacuole; but the rod may have the form of a crescent (Fig. 95).

The tentative conclusion to which I have come with regard to this body is, that it represents the nucleolar substance of the nucleus of the spermatid, and that it subsequently passes into the mass of chromatin, with which it becomes homogeneously mingled. My evidence for this is as follows. Very soon after the second division of the spermatocytes a body is seen in the nucleus, which is quite distinct from the rest of the stainable substance of the nucleus (Plate **3**, Figs. 77, 78, 83, 85). It (*cres.*) lies at first among the chromatic granules of the nucleus, but is distinguishable from any of the latter by its greater size and deeper color (Figs. 57, 102–104). Then it comes to lie in the vacuole of the nucleus (Plate **3**, Figs. 94–98). At length, what I consider its remains are found for some time faintly discernible in the chromatic mass of the head of the immature spermatozoön (Figs. 88 and 106–108). In later stages (Fig. 110) this body is not to be distinguished from the rest of the chromatic mass. I was at first inclined to believe that this body allied itself with the centrosome to help in forming the neck-body, but was soon convinced that this is not true, because I observed that the two parts of the centrosome and this problematical body exist at the same time in the same spermatid (Figs. 97, 98). In Figures 90, 92, and 106 the body in question is seen in contact with the chromatic mass, and in Figures 103, 104, it is nearly included in the chromatic crescent. Later, as already indicated, it becomes indistinguishable from the rest of the head of the spermatozoön. Accordingly, I am unable to determine whether or not it forms any definitely limited portion of the head.

At the time when the two daughter cells separate from each other at the conclusion of the second division of the spermatocytes, the *chromatic*

elements of each resultant spermatid present the appearance of a compact irregularly shaped nuclear mass (Plate **2**, Figs. 41, 53). After the formation of a nuclear membrane there is a considerable swelling of the nucleus as a whole, and the chromosomes break up into a large and variable number of granules of unequal size (Plate **3**, Figs. 80–86 and 103, 104). The fine granules later fuse into a homogeneous crescentic mass (Fig. 105). Cross sections of the head of the spermatid appear circular (Fig. 110[a]). There is, therefore, no flattening of the head in Caloptenus.

The above results, thus briefly stated, may now be compared with the investigations of other students published since my former paper was written.

Rückert ('94) has found in the oögenesis of Copepods many stages in the origin of the Vierergruppen similar to what I find in the spermatogenesis of Caloptenus. (Compare my Figs. 9 and 15–17 with his Figs. 23, 24.) He finds that there is one longitudinal splitting of the chromatic segments. Then each of the daughter segments divides transversely. On this point Rückert says (pp. 308, 309): "Sie [the transverse division] tritt, wie erwähnt, im Stadium der Fig. 11, also dann, wenn die Chromosomen gegen den Aequator des Keimbläschens vorzurücken anfangen, deutlich hervor als eine allen Doppelstäben gemeinsame Erscheinung. Indessen lässt sich die Vorbereitung zur Querspaltung schon in jüngeren Stadien (Figs. 8–10) erkennen, an manchen Doppelstäben sogar recht deutlich." Since I do not find a longitudinal splitting, it may seem difficult to compare Rückert's account with mine. In reality, however, a very close agreement exists. Rückert states that ordinarily the transverse division is first manifest when the pairs of segments begin to move toward the equator of the spindle. This corresponds to my second mode of formation of Vierergruppen as described and figured (Diagrams 7–10) in my former paper (Wilcox '95, p. 10). In this case the four ultimate chromatic elements of a ring are not to be distinguished until the rings are about to take their place on the spindle. While Rückert admits that his transverse division is indicated much earlier in some cases, he adds (pp. 308, 309): "Vollends aber würde es falsch sein, in den Fäden noch jüngeren Stadien, in welchen sich das Chromatin noch nicht konzentriert hat, alle Unterbrechungen des färbbaren Teiles als Vorläufer der späteren Querteilung zu betrachten. Eher liesse sich die in früherer Zeit, namentlich in Fig. 8, so deutliche Ansammlung des Chromatins in den anschwellenden Fadenenden vielleicht mit der späteren Querteilung in genetischen Zusammenhang

bringen." My first mode of Vierergruppen formation (Wilcox, '95, Diagrams 3–6, p. 10) would correspond to this condition (Figs. 7, 10). When all the chromatic substance of a segment has collected itself at the two ends of the segment, a "transverse division" has already taken place, so far as the chromatin is concerned, although the two masses are held in connection by means of linin fibres.

The bodies at the ends of the spindles in Rückert's Figures 14, 18, 19^{b}, and 29^{b}, seem to me of rather doubtful nature. The evidence given is not sufficient to satisfy me that they are centrosomes, and of nuclear origin, as Rückert believes. Rückert ('94, p. 337) combats Weismann's idea that reduction is accomplished in both of the two divisions: "Ich meinerseits möchte dieselbe nicht geradezu als falsch bezeichnen, aber doch mindestens als unzureichend, weil sie auf die Bildung der Vierergruppen keine Rücksicht nimmt, sondern den Anschein erweckt als ob die sämmtlichen, für alle vier Enkelzellen zusammen bestimmten Chromatinstückchen von einander unabhängig wären und in beliebiger Gruppierung in die erste Reifungsspindel eintreten könnten."

It thus seems as if Rückert considered the mere idea of chromosomes arising independently as too ridiculous for any one to maintain. I could wish he had explained why in his opinion it is unreasonable to suggest such a possibility. I believe that in the spermatogenesis of Caloptenus, at any rate, the chromosomes arise quite independently of one another in the prophases of the first maturation division. Furthermore, the chromosomes do not appear on the first maturation spindle in *reduced* number; but there has been instead a *doubling*. We must remember that each ring has the value of four chromosomes.

Lee ('95) has come to the conclusion that the problematic body of Platner and Zimmermann, the "Zellkoppel," arises from the remains of the interzonal filaments. The main results of his investigations, which were made upon the spermatogenesis of Helix sp., may best be stated in his own words (p. 46): "Dans les spermatogonies et les spermatocytes de l'Hélix, le fuseau caryocinétique persiste en général pendant sa regression sous la forme d'un corps pâteux, unissant les deux cellules issues de la cellule qui l'a formé. Ce corps est le corps problématique de Platner. Les corps ainsi formés par le fuseau regressif persistent normalement à travers plus d'une génération cellulaire; et de la fusion de deux ou plusieurs de ces restes fusoriaux appartenant à des générations successives, résulte la formation d'une chaîne de ponts fusoriaux reliant entre elles un nombre considérable de cellules. Ces chaînes sont le 'Zellkoppel' ou ligament intercellulaire de Zimmermann."

I have not seen these structures in the spermatogonia and spermatocytes of Caloptenus, and my failure to see them can hardly have been due to the use of methods not suited to the differentiation of such structures; for the interzonal filaments are clearly shown in Figures 31–35 and 39–44. Very similar conditions are seen in the first division of the spermatocytes, but I have not been able to discover that the remnants of the spindle persist from one cell generation to another. The spindle remains do persist, however, after the second division of the spermatocytes, and as I have shown, go to form in the spermatid of Caloptenus the body which I have called the "Nebenkern," just as Field ('93) has shown for Echinoderms.

I cannot keep entirely free from the present active controversy as to the existence, origin, and meaning of the *centrosomes*. So far as my own observations on spermatogenetic material go, there certainly are distinct sharply contoured bodies at the point toward which the fibres converge at either end of the spindle. Each body is single, and I cannot resolve it, even with a magnification of 1,500 diameters. I have represented in Plate **1**, Figs. 1 and 2, centrosomes during the division of the spermatogonia; in Plate **1**, Figs. 19–25, during the first division of the spermatocytes; in Plate **2**, Figs. 31, 38, Plate **3**, Fig. 111, during the second spermatocyte division; and in Plate **3**, Figs. 77–110, during the metamorphosis of the spermatids. Between the last division of the spermatogonia and the first spermatocyte division, I am unable to say what becomes of the centrosomes. From the first maturation division to the formation of the spermatozoön, the centrosome maintains, as I believe, its individuality, and undergoes only slight changes. My material was not favorable for following the early history and origin of the centrosomes, and I therefore cannot from personal experience criticise the following account by Reinke ('94, p. 276): "Ich halte demnach die Centralkörper nicht für Gebilde sui generis, wie etwa den Kern, und möchte sie auch nicht für ein Organ der Zelle, das an einer bestimmten Stelle liegen müsste, erklären, sondern ich halte sie für organoide Gebilde, die sich nach Bedürfniss aus kleineren ähnlichen, im Protoplasma überall vorhandenen Gebilden (tertiären Centren) entwickeln können, also potentiell in der Marksubstanz der Zelle überall vorhanden sind," etc.

Reinke thus considers centrosomes as *organoids*, not organs of the cell. This may be the true origin of the centrosomes, but I firmly believe that in Caloptenus they are not broken up into microsomes after the first division of the spermatocytes.

Figure 25 (Plate 1), which is drawn from a preparation killed in Hermann's fluid, and stained by Heidenhain's iron-hæmatoxylin method, shows the condition of the centrosomes during the first maturation division, some of the spindles being seen in polar view, others in equatorial. All the centrosomes are definitely outlined bodies, and cannot possibly be confounded with the dark area of converging fibres at the poles of the spindles. When Heidenhain's hæmatoxylin is followed by orange, the spindle fibres take the orange stain, but the centrosomes are colored black by the hæmatoxylin. Ordinarily there is no clear area around the centrosome, but radiations are easily seen in the surrounding cytoplasm.

Eismond ('94) has discussed the occurrence and meaning of the attraction spheres and centrosomes. He says (p. 266): "Da einmal die Attractionssphären nichts anderes sind als Bezirke des Zellleibes, lediglich dadurch ausgezeichnet, dass daran das protoplasmatische Gerüstwerk zu einer verhältnissmässig feineren und also dichteren Zusammenfügung gelangt, — da sie ferner keine, wenigstens aber keine sicher nachweisbare Andeutung von besonderer biochemischer Natur und irgend einer besonderen morphologischen Differenzierung zeigen, indem sie — wie ich dieses annehmen zu müssen glaube — nur gewissen structurellen Configurationen des protoplasmatischen Gerüstwerkes ihren Ursprung zu verdanken haben, — da ausserdem jegliche Umwandlungen der Attractionssphären, sei es mitsammt dem Centrosom, sei es ohne dasselbe, eine so grosse Variabilität offenbaren und sogar manchmal zum Trotze ganz fehlen dürfen, so glaube ich, wie schon oben bemerkt wurde, die Vermutung für ganz berechtigt halten zu können, dass es sich hier allerdings nicht um Umbildungen eines polymorphen, zugleich aber constanten Cytoorgans handelt, sondern dass wir es mit etwaigen endokinetischen Erscheinungen zu thun haben, welche an der äusserst wandelbaren Gerüstsubstanz des Zellleibes ablaufend, das Gerüstwerk der letzteren zu jeglichen Configurationen bringen."

Here is a whole theory of these structures stated in one sentence! But Eismond's argument seems to me considerably colored by his general idea of the structure of protoplasm. He accepts Bütschli's soap-bubble theory of protoplasm, and by its aid attempts to explain away both centrosomes and attraction spheres. Now, in Caloptenus the centrosomes are just as truly specialized bodies — both chemically and physically — as are the chromosomes. They have as sharp an outline; with the use of iron-hæmatoxylin and orange, as previously mentioned, the centrosomes are clearly differentiated, — they being stained black,

while the spindle fibres are colored orange. The distinctness of the centrosomes is not exaggerated in Figure 25. No one could think them to be simply the points to which the spindle fibres converge. The preservation of the histological condition is, moreover, in other respects very good; there has been no local condensation of the protoplasmic structure sufficient to account for them. In some stages of spermatid metamorphosis the centrosome is the most deeply stained and most distinctly contoured body in the spermatid, not excepting the chromatic mass of the head. Moreover, Bütschli's theory seems to me insufficient to explain all protoplasmic structures and all organs of the cell.

Reinke ('94, p. 273) takes, as it seems to me, a much more reasonable position: "Ich sehe nun in meinen Präparaten alle drei Dinge: Körner, Fäden, die zum Theil Netze bilden und schliesslich Waben oder Schäume." It is very difficult for me to believe that spindle fibres are simply the lines along which the walls of the minute cells of a honeycomb structure meet. How, if this theory is valid, could we get cross sections of fibres such as are seen in Figure 42 (Plate **2**)? Again, if the apparent spindle fibres are due to the much elongated form into which the honeycomb cells are compressed, I have difficulty in understanding how are to be explained the fibres bridging over the space between two cells, which, except for the fibres, are already completely separated (Plate **2**, Fig. 31). If we grant that during division there is a mechanical force of sufficient intensity and definiteness to produce apparent fibres from the honeycomb structure of the protoplasm, the same force must remain in operation during the metamorphosis of the spermatids, in order to keep the remnant of the spindle fibres and their final product, the Nebenkern, in the condition of a distinctly modified portion of the protoplasm throughout this long period. Furthermore, how could we, on this assumption, account for the intercellular ligament described by Lee ('95), which persists through several generations?

These structures are, to my mind, something more than mere "configurations" of the protoplasmic honeycomb, as Eismond would have us believe. They rise to the dignity of cell organs. I do not wish to maintain that the centrosome, Nebenkern, and spindle fibres preserve their individuality indefinitely. They may not be directly concerned in the transmission of hereditary substance, but they *do possess a special chemical* nature, and they are of some *morphological significance*. We are not justified in considering these structures explained by the simple statement "dass wir es mit etwaigen endokinetischen Erscheinungen zu thun haben." If the centrosome and attraction sphere have no morpho-

logical value, and no chemical property different from that of the surrounding protoplasm, we have a right to ask why they are tolerably constant in number, position, and relationship to other parts of the cell.

The recent studies of Wheeler, Mead, and Wilson and Matthews upon fertilization suggest the need of further inquiry into the function of the centrosome.

Wheeler ('95) has found in Myzostoma archoplasm and centrosomes in connection with the *female* pronucleus, but never with the male pronucleus. This is an interesting observation, but it ought to be confirmed by further study, since it is directly opposed to the results of Mead ('95), who found neither archoplasm nor centrosomes belonging to the female pronucleus of Chætopterus, these structures being introduced into the egg by the spermatozoön. On this point Wilson and Matthews ('95) have reached results in the study of Echinoderms which agree with those of Mead. The conclusion reached in both cases is essentially the same, and is summarized by Wilson and Matthews (p. 320) in these words: "The archoplasm of the first cleavage-amphiaster is developed entirely from, or under the influence of, the spermarchoplasm ('spermocentre' of Fol), and this is derived not from the apex of the spermatozoön, but from its base, undoubtedly from the middle piece (Toxopneustes, Arbacia)."

In the spermatids of Caloptenus I have traced the centrosome until it becomes the middle piece, and hope to be able to study the early stages of fertilization in the eggs of some insect in the near future.

My warmest thanks are due to Prof. E. L. Mark for the kind advice and assistance which I have received from him during this investigation.

CAMBRIDGE, April 28, 1895.

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EXPLANATION OF FIGURES.

Figures 1–13 (Plate 1) and 39–43 (Plate 2) are magnified 1,000 diameters; all others, 680 diameters.

PLATE 1.

Caloptenus femur-rubrum.

Figs. 1, 2. Spermatogonia in dyaster stage.
Fig. 3. Spermatogonium in resting condition.
Figs. 4–18. Spermatocytes, various *prophases* of the *first* division, — spirem, dumb-bell, and ring stages.
Figs. 19–25. Spermatocytes during the *first* division.
Figs. 26, 27. Polar view of spermatocytes during *second* division.

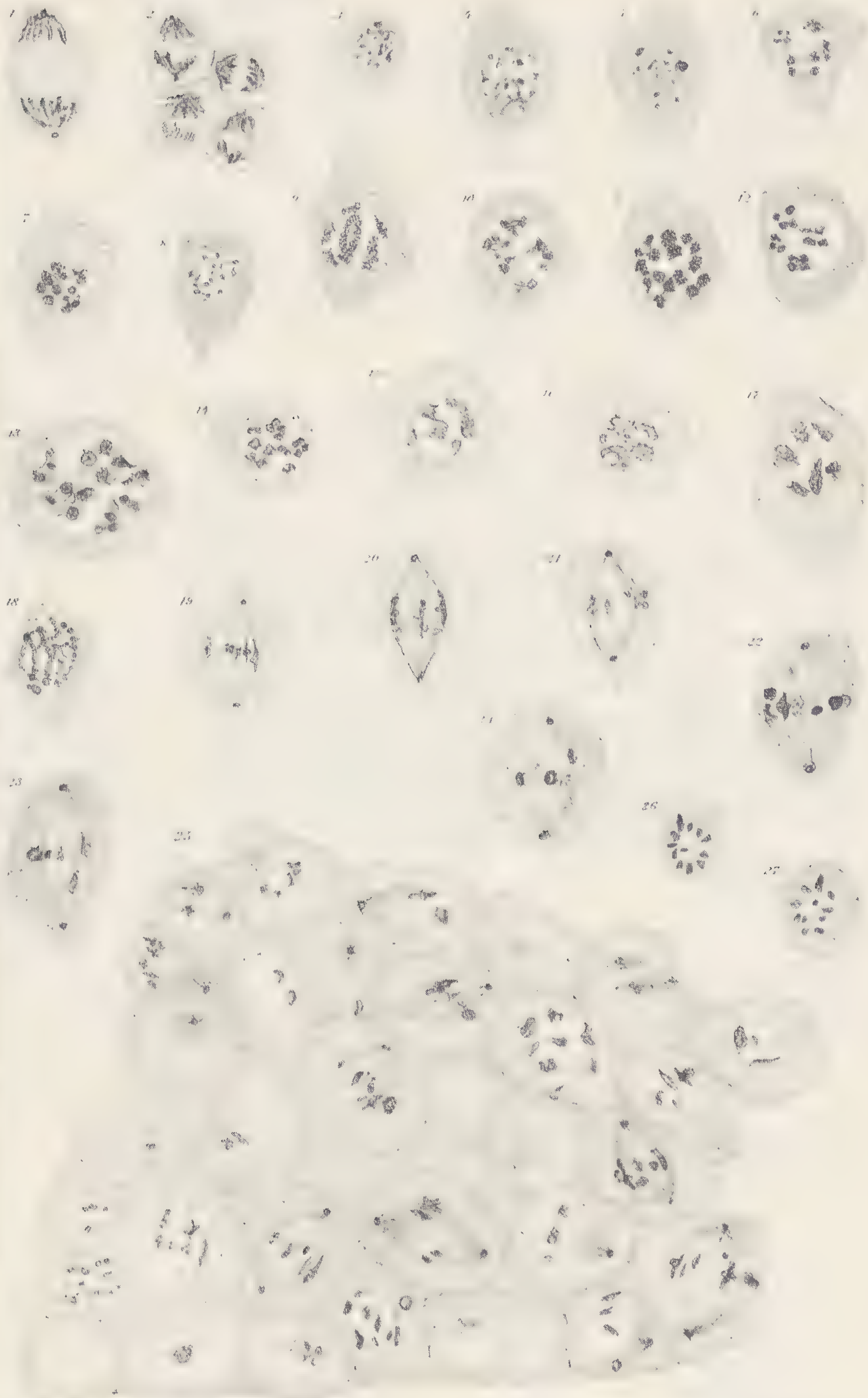

PLATE 2.

Caloptenus femur-rubrum.

Figs. 28–41, 44, 45. Equatorial view of spermatocytes during *second* division. Figs. 39 and 40 show thickened interzonal filaments.

Fig. 42. Polar view of spermatocyte during *second* division.

Fig. 43. Spermatocyte during *second* division; interzonal filaments cut obliquely.

Fig. 46. Equatorial view of spermatocyte during *first* division.

Fig. 47. Spermatocyte, equatorial view at the end of *second* division.

Figs. 48–55. Spermatids in early stages of metamorphosis.

Figs. 56, 76. Spermatids soon after second spermatocyte division.

Figs. 57–60. Spermatids in advanced stages of metamorphosis.

Figs. 61–75. Spermatids in various stages of metamorphosis, arranged approximately in the order of their ages.

PLATE 3.

Caloptenus femur-rubrum.

Figs. 77–110ª. Spermatids in various stages of metamorphosis.

Trirhabda tomentosa.

Fig. 111. Spermatocyte at end of *second* division.
Figs. 112–114. Spermatids in metamorphosis.

Cotalpa lanigera.

Fig. 115. Spermatocytes, *first* division, showing the arrangement of cells in a cluster.
Fig. 116. Spermatocyte; chromatin in the ring stage.

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THE DEVELOPMENT OF THE WING SCALES AND THEIR PIGMENT IN BUTTERFLIES AND MOTHS.

BY ALFRED GOLDSBOROUGH MAYER.

WITH SEVEN PLATES.

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No. 5. — *The Development of the Wing Scales and their Pigment in Butterflies and Moths.*[1] By Alfred Goldsborough Mayer.

This research has been carried out under the direction of Professor Edward L. Mark, to whom I am so fortunate as to be indebted for much valuable advice and happy suggestion.

During the summer of 1895 I carried out a series of observations upon the development of the colors in the pupal wings of Danais plexippus (archippus) Fabr. and Callosamia promethea Linn. The results of these observations will be published in connection with a paper entitled, "On the Color and Color Patterns of Moths and Butterflies," which it is expected will appear during the present year. I may state here briefly the main conclusions reached on those subjects.

It appeared that during early pupal life the wings are as transparent as glass, but that from five to ten days before emergence they become opaque, and pure white. After this a dull ochre-yellow or drab color suffuses the wings, tingeing all parts excepting those that are destined to become the white spots of the mature wing, these always remaining pure white. About twenty-four hours after the appearance of the dull yellow suffusion the mature colors begin to show themselves. They arise, faint at first, in places near the centre of the wings, and are distinguished by the fact that they first appear upon areas *between* the nervures, never upon the nervures themselves. Indeed, the last places to acquire the mature coloration are the outer and costal edges of the wings, and the nervures.

The progress of the color development is illustrated in Plate **7**, where Figures 53–70 represent the color development in Callosamia promethea, and Figures 71–74 the same thing for Danais plexippus. Figure 53 represents a fore wing of C. promethea in the white stage, and Figure 54 is a scale taken from the same wing. Upon treating the scales in this stage with clove oil or oil of cedar-wood they become practically invisible under the microscope, thus demonstrating that there is no pig-

[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy at Harvard College, under the direction of E. L. Mark, No. LIX.

ment within them. Figure 55 represents a scale from one of the light-drab colored areas of the mature wing, and upon comparing it with Figure 54 it becomes apparent that it is much darker in color, and yet it is taken from the lightest colored area of the wing. Figure 56 is a view of the under surface of the hind wing of a male, and Figure 57 of the under surface of the fore wing of a female moth. The two figures illustrate a very early stage of color development, and from them it will be seen that the colors first appear, as I have stated, *between* the nervures. The upper surfaces of the wings are as yet of a uniform dull yellow color. Figures 58–64 show successive stages in the color development in the male, and Figures 65–70 the same for the female. In the stages represented in Figures 60 and 67 the male and female wings are very similar in appearance, except that the general tone of the male wing is grayish, that of the female cinnamon-brown. The ground color of the male wings, however, soon deepens into jet black, as is shown in Figures 61 and 62.

Figures 71–74 show successive stages in the color development of the fore wing of Danais plexippus. In Figure 71 is seen the wing in the dull yellow stage, showing the white spots already standing out against the dull yellow background. In Figure 72 the black coloration has begun to appear near the centre of the wing, and in Figure 73 this black coloration has spread along the edges of the nervures, and the rufous ground color of the mature wings has begun to appear in places between the nervures. In Figure 74 the black color has finally suffused the nervures. The base of the wing and the submedian nervure are the only parts that still remain dull yellow. It is evident that in Danais plexippus, as in Callosamia promethea, the central areas of the wings are the first to exhibit the mature colors, and that the nervures and costal edges of the wings are the last of all to be affected.

These results confirm and amplify the previous researches of Schäffer ('89) upon Vanessa urticæ; van Bemmelen ('89) upon Vanessa urticæ, Pyrameis cardui, and Pieris brassicæ; Urech ('91) upon several Vanessas; and Haase ('92) upon various species of Papilio.

The primary object of the present research is to determine the manner in which the wing scales of the Lepidoptera acquire their pigmental colors. I have also traced the general development of the wings from the condition found in the mature larva up to that of the imago. The paper will be divided into four parts: (1) The General Development of the Wings and Scales; (2) The Development of the Pigment within the

Scales; (3) The Probable Physical and Chemical Nature of the Pigments; (4) A Summary of Conclusions believed to be new to Science.

The material made use of in the research consisted of larvæ of Danais plexippus Fabr. and Pieris rapæ Linn., and pupæ of Vanessa antiopa Linn., Danais plexippus Fabr., Pieris rapæ Linn., Papilio turnus Linn., Papilio asterias Fabr., Callosamia promethea Linn., and Samia cecropia Linn.

The larvæ were killed in Perenyi's fluid warmed to about 55° C. In the case of the pupæ the outer chitinous cuticula was peeled off from one of the wings, in order to allow a more perfect penetration of the killing fluids. The reagents used in killing the pupæ were, (1) hot saturated solution of corrosive sublimate in 35% alcohol, (2) Perenyi's fluid warmed to about 55° C., (3) P. Mayer's picronitric mixture, and (4) a saturated solution of picric acid in 50% alcohol. The best results were obtained from Perenyi's fluid; corrosive sublimate, however, gave good histological results, but it often failed to penetrate the chitinous cuticula. Various stains were tried, such as Kleinenberg's hæmatoxylin, Ehrlich's hæmatoxylin, the Ehrlich-Biondi mixture, and safranin. All staining was done upon the slide, and the best results were obtained from Kleinenberg's hæmatoxylin, either alone or followed by safranin. The latter method brought out a sharp differentiation between the protoplasm, which was stained blue, and the chitin, which was tinged pink. Safranin was found to be an excellent stain for chitin. Paraffin sections were employed, and were usually 6.6 μ in thickness.

1. The General Development of the Wings and Scales.

It appears from the researches of Landois ('71) and Pancritius ('84) that the Anlagen of the wings may be found in young Lepidopterous larvæ only 4 mm. long. They appear in the second and third thoracic segments of the larva as infolded hypodermal pockets penetrated by tracheæ. Figures 1 and 2 (Plate **1**) give the appearance of a frontal section through the left wing of a mature larva of Pieris rapæ (Danais plexippus exhibits the same general appearance) viewed from above.

Figure 2 is merely a diagrammatic reproduction of Figure 1, and is intended to show more clearly the manner in which the hypodermis is folded. In both figures, *cta.* indicates the outer chitinous cuticula of the larva; *h'drm.*, the hypodermis; *a.*, anterior; *p.*, posterior; and *mbr. m.*, the middle membrane, which encloses the tracheæ. The thickened por-

tion of the hypodermis in Figure 1 — which is identical with the heavy black portion of Figure 2 — is destined to become the wing, and it is evident from an inspection of either of these figures that this organ is really a folded portion of the hypodermis itself, enclosing a thin layer of mesodermal tissue (*mbr. m.*). The conditions are, however, somewhat complicated. The wing-pad proper is a pocket-like *out*folding of the hypodermis, which, for want of room, is more or less folded upon itself. This pocket, instead of lying exposed between the hypodermal covering of the larva and its cuticula, is protected by being sunk into a deep sac-like *in*folding of the hypodermis, the walls of which are very much thinner than those of the wing-pad, and indeed thinner than the rest of the hypodermis. The walls of the infolded sac follow quite closely the foldings of the wing-pad itself. It is evident that, in penetrating from without inward, one would traverse in the region of the wing-pad no less than five layers of the hypodermis: first, the outer and inner layers of the operculum-like fold of the hypodermis which covers in the wing; then, in succession, the thick outer and inner layers of the wing-pad; and, finally, the thin inner layer of the infolded sac.

The tracheæ (*tr.*, Plate **1**, Figs. 1 and 2) penetrate between the two thickened layers of the wing-pad. The outermost of these two layers is destined to form the upper wall of the future wing, while the inner one becomes the lower wall of the wing. Figures 3 and 3 *a* (Plate **1**) are representations of the histological condition of the cells which compose the wing-pads. Figure 3 is a portion of a cross section through the whole thickness (i. e. both walls) of the wing-pad, and Figure 3 *a* is a small portion of a longitudinal section of the upper wall only. The cells are much more crowded in the longitudinal direction than they are in the direction across the wing. It is evident that these young wing-tissue elements are really spindle-shaped hypodermal cells; the nucleus being found in a swollen portion situated somewhere near the middle of their length. The inner ends of these spindle-shaped cells are often seen to be fused to a double membrane (*mbr. m.*), occupying the space between the two walls of the wing-pad. In very old larvæ, however, this membrane is usually absent, and the inner portion of the cells which constitute the wing tissue end free, as is seen in Figure 3 *a*. The membrane, when present, forms a sort of sac, which encloses the tracheæ of the wing, and is continuous with the basement membrane which underlies the general hypodermis of the larva.

Pancritius ('84) describes the development and histological condition of the wing in the larvæ of several species of Lepidoptera, and his account

agrees very well with what I find in the larvæ of Pieris rapæ and Danais plexippus.

When the larva changes into a chrysalis, the wings expand to about sixty times their former area, and as a consequence the cells which compose the wall of the wing-pad, being no longer crowded together, lose their spindle shape and flatten out into a pavement epithelium.

Figure 4 (Plate **1**), and Figures 5, 6 (Plate **2**), represent the condition found during the winter months in the pupæ of Samia cecropia, but this condition is also quite typical for the overwintering pupæ of Callosamia promethea, Pieris rapæ, Papilio turnus, and Papilio asterias. The same condition is likewise found in the young summer pupæ of Vanessa antiopa.

Figure 4 is a longitudinal section taken near the free lower edge of the chitinous wing sheaths of the chrysalis, and Figure 5 is a small portion of the same section more highly magnified. Figure 6 is a view looking down obliquely upon the epithelium of the wing, the outer chitinous cuticula of the pupa having been removed.

The chitinous outer cuticula (*cta.'*) of the pupa encloses each wing in a separate sheath, — as is shown in Figure 4, where the upper wing is seen lying above the lower, — and exhibits a layered or stratified condition; it is deeply pigmented near its outer surface. This is best seen in Figure 5 (*cta.'*). A delicate structureless membrane, the inner cuticula (*cta.''*, Figure 5), lies between the outer cuticula and the hypodermis.

It is evident that in this stage each wing consists of a hollow bag, the wall of which is composed of a single layer of hypodermis cells (*h'drm.*, Figs. 4, 5, and 6). These hypodermis cells contain large oval nuclei, which exhibit chromatin granules arranged near the periphery.

The middle membrane (*mbr. m.*, Fig. 3, Plate **1**) has disappeared as such, and in its place one finds a delicate membrane (*mbr. pr.*) lining the whole interior of the wing-bags. This is the "Grundmembran" of Semper ('57), who showed that it was produced by mesenchymatous cells, which applied themselves to the deep surface of the hypodermis, and sent out lateral processes, serving both to connect the cells with one another and to give them a stellate form. Semper found that these stellate cells secreted an intercellular substance, filling up the interstices of the network formed by them, and that this substance, together with the metamorphosed cells that produced it, finally became the thin structureless membrane to which he gave the name Grundmembran. This explanation I believe to be entirely correct.

In Figure 6 we have a surface view of a portion of this network (*mbr. pr.*), formed by the nucleated stellate cells, and in Figure 5 the membrane is seen edgewise. In Figures 4 and 5 it is to be observed that this membrane is widely separated from the hypodermis as a whole, though from nearly every hypodermis cell a greatly elongated process (*prc.*) reaches down to and unites with the Grundmembran. This separation of the two cell layers, and the consequent formation of a space between them, were also observed by Semper, but he appears not to have observed that this space contains lymph corpuscles. I find that these corpuscles are present in large numbers, and this fact complicates the question as to the origin of the formative cells of the scales, — a question to the discussion of which I shall return later. The presence of lymph corpuscles between the Grundmembran and the hypodermis renders it probable that the former is not, as Semper supposed, absolutely uninterrupted. However, I am not able to affirm from personal observation that there are direct communications between the sub-hypodermal spaces and the chief lumen of the wing. It is rather a matter of inference.

In another particular, too, my observations add to the account given by Semper, for at rather regular intervals the Grundmembran of one wall becomes continuous with that of the other by means of hollow tubes (*tb.*), which seem to be formed by the folding of the membrane itself (Figs. 4 and 5). The cavities of these tubes are direct continuations of the sub-hypodermal spaces of the upper and lower walls of the sac, which are thus put into communication with each other at frequent intervals, and it is worthy of note that leucocytes are frequently found within these tubes.

Slender thread-like prolongations of the hypodermis cells (*prc.*, Figs. 4, 5, 7, and 8) are seen to extend inward from the hypodermis to the Grundmembran, as already stated. Each of the hypodermis cells gives rise to one, and only one, of these processes. The process is rather sharply marked off from the cell from which it arises ; but after tapering rapidly for a short distance it is prolonged into a thread-like structure many times as long as it is thick ; this diminishes slowly in calibre until it reaches to and fuses with the Grundmembran. It is probable that at first the hypodermis cells are simply converted into columnar epithelium, and that the sharp distinction between cell body and cell process is brought about only at the time when the process becomes greatly elongated. Occasionally a hypodermis cell is seen without any such process.

The wings are still hardly more than simple outpocketings of the general hypodermis of the chrysalis. In fact, in the larva itself the

general hypodermis of the body is lined on the inner side by a thin membrane, coincident in relative position with the Grundmembran of the wings, and where this membrane is stretched, as in Figure 25, Plate **4** (*mbr. ba.*), — which represents a cross section of the mid-dorsal region just back of the head, where the cuticula splits when moults occur, — we see that the hypodermis cells send out processes which are connected with the membrane. This reminds one of the condition of the processes (*prc.*, Figs. 4, 5) in the pupa.

But to return to the discussion of the condition of the wings in the over-wintering pupæ. There is one more point to be noticed. The wings are filled with blood, or more properly speaking hæmolymph, and this fluid contains blood corpuscles, which exhibit several shapes (*leu'cy.*, *leu'cy.'*, *leu'cy.''*, Figs. 4 and 5). Some of these corpuscles (*leu'cy.''*, Fig. 5) are much elongated or spindle-shaped, and their nuclei are oval. At one or occasionally both ends they exhibit long tail-like projections. Others, however (*leu'cy.'*, Figs. 5, 6, and 7), which are found only in the very young pupæ, are usually rounded or only slightly angular, and are often so vacuolated that the nucleus is crowded to one side and assumes a crescentic form. These vacuolated cells appear to be blood corpuscles which are degenerating, for it is certain that there are no vacuolated blood corpuscles to be met with in the larvæ, or in the older pupæ.

It seems probable to me that these transitory vacuolated corpuscles are the "Fettkörper" of Semper ('57, p. 327), for I find no true fat cells in the hæmolymph. Schäffer ('89) has shown that the leucocytes found in Lepidopterous larvæ are morphologically equivalent to fat cells that have remained in an embryonic condition. He finds that the leucocytes are chiefly derived from large masses of fat cells which lie near the Anlagen of the wings in the larva, or from those which constitute the matrix of the tracheæ. Most of the cells composing these masses are true vacuolated fat cells. Some of them, however, remain in an embryonic condition, never becoming vacuolated, and, separating off from the mass, become free in the body cavity. The cells which are thus set free become leucocytes.

The wing remains in the simple histological condition just described until about three weeks before the insect is destined to emerge from the chrysalis. Then (Plate **2**, Fig. 7) certain of the hypodermis cells (*cl. frm.*), which occur at regular intervals, begin to be modified. They begin to increase slightly in size, to project a little above the level of the ordinary hypodermis cells, and, most remarkable of all, to acquire each a vacuole. The cells which have become thus modified are destined

to secrete the scales; they are the formative cells of the scales, — the "Bildungszellen" of Semper ('57).

This is a most important stage, for it gives the best evidence yet produced to prove the origin of the scale-producing cells. The fact that these cells contain each a vacuole, and that they are large and deeply staining, suggests that they may have arisen from the migratory leucocytes, some of which, as we have seen, are in like manner vacuolated, and stain deeply. There are, however, serious objections to this view. In the first place, the scale-producing cells are destined to secrete cuticula, like all ordinary hypodermis cells, and, so far as we know, this is not a usual function of mesenchymatous cells. In addition to this there are important considerations of a more direct nature, which point to the hypodermis, rather than to the mesenchyme as the source of these cells; for at this stage some of the formative cells are still connected by their deep ends with the Grundmembran by means of protoplasmic prolongations of their own cell bodies, just like the indifferent hypodermis cells. To my mind the evidence is perfectly satisfactory that the formative cells are simply *modified hypodermal cells*.

In the next stage (Plate **2**, Fig. 8) the scale-producing cell (*sq.*) has already grown outward as a blunt process, which bends distad, or towards the outer edge of the wing. The protoplasmic prolongations (*prc.*) at the deep ends of the young formative cells have now nearly all disappeared, only a remnant of them being occasionally seen, as in the case of cell *cl. frm.* (Fig. 8). There is usually only a single vacuole in each of these young cells, but sometimes there are two, as in the case of the cell just referred to.

Schäffer ('89, p. 643, Tafel XXX. Fig. 36) has described the conditions found in the pupal wings of Vanessa urticæ about three days after pupation. The wing is in a slightly more advanced stage than the one shown in my Figure 8 (Plate **2**). The formative cells are quite large, and each contains several small vacuoles (Secretbläschen); it is also worthy of remark that the formative cells now exhibit no traces of protoplasmic processes. My Figures 7 and 8 were drawn from pupæ of Vanessa antiopa, which were kindly given me by Mr. Samuel Henshaw.

The next older stage known to me is represented in Figure 28 (Plate **5**), and was drawn from a pupa of Danais plexippus. The formative cells (*cl. frm.*) have greatly increased in size, and the vacuoles, if they exist in this species, have entirely disappeared. The upward projections which are to form the scales (*sq.*) have grown outward to a much greater extent than in the stage last described. The hypodermis (*h'drm.*) is

now thrown up into a regular series of ridges, which run across the wing, that is to say, at right angles to the general trend of the nervures. Each ridge corresponds in position with a row of formative cells, and each furrow with the interval between two adjacent rows. Indeed, the nature of the folding is such as to show clearly that its character depends on the growth and arrangement of the formative cells. As a consequence of this arrangement, the scales always project from the tops of these ridges. The Grundmembran (*mbr. pr.*, Fig. 8) has not participated in this folding, and the deep processes (*prc.*, Fig. 8) of the hypodermis that once extended to this membrane have largely disappeared.

Figures 9 and 10 (Plate **2**) represent a still more advanced stage of the pupal wings, drawn in this case from Danais plexippus, about eight days before emergence from the pupa; the condition is the same, however, in all the other forms examined by me, a similar condition occurring in Callosamia promethea about eleven days before the moth issues. Figure 10 is a portion of a longitudinal section through the wing, which therefore cuts across the ridges. Figure 9 is a much more highly magnified view of one of these ridges. In Figure 10 *cta.'* represents the outer chitinous cuticula of the pupa, and *cta.''* is the inner cuticular membrane, which we saw in Figure 5 lying almost in contact with the hypodermis cells. Now, however, it has been pushed outward by the development of the scales (*sq.*). It is evident that in the stage represented in Figures 9 and 10 all traces of the protoplasmic processes which bound the hypodermis to the Grundmembran have disappeared. The Grundmembran, indeed, is now nothing more than a simple homogeneous structure, the stellate cells which were so evident in Figure 6 (Plate **2**) having almost entirely disappeared. In most places it has the appearance of a structureless membrane lying below the hypodermis, but here and there one finds that its outer surface is striated, as shown in Figures 26 and 27 (Plate **4**). The striæ run, for the most part, parallel to one another, and always across the wing; that is to say, perpendicular to the trend of the nervures. In appearance they remind one of the striæ which are found upon the scales, excepting that they are very much farther apart. Figure 26 is an edge view of this membrane; Figure 27, a view of its outer surface.

Figure 12 (Plate **3**) is drawn from a slightly later stage of Danais plexippus. In this case the Grundmembran presents nearly the same appearance as in the stage at present under discussion, and though the specimen is a little older than the one last described, the membrane still exhibits traces of the nuclei (*nl.*) of the stellate cells which pro-

duced it; the nuclei being seen through a folded-over portion of the membrane.

The structure and arrangement of the formative cells, and of the undifferentiated hypodermis cells, are shown in Plate **2**, Fig. 9. The body of the large formative cell (*cl. frm.*) lies wholly below the level of the hypodermis cells, and sends a protoplasmic process upward to form the scale (*sq.*). The nucleus of the formative cell is large, and spherical or ovoid in shape. At this stage it always exhibits a small highly refractive nucleolus situated near its centre. The chromatin consists of small curved and broken rods or filaments, and appears to be arranged in a spherical shell about the nucleolus as a centre. The scale (*sq.*) at this stage is a minute flattened chitinous bag filled with protoplasm. It may be here noted that, as long as the scales remain full of protoplasm, they appear as transparent as glass, but when the protoplasm begins to shrink out of them, as it does later, and air takes its place, they become pure white.

The hypodermis cells (*h'drm.*) have greatly changed in appearance since the stage represented in Figures 5 and 6. They are no longer sharply separated by well defined cell walls, but the protoplasm of adjacent cells has apparently become confluent. Nevertheless, each cell territory is quite well marked out by the peculiar arrangement of the finely granular contents of the cells. The region of the boundary between cells is characterized by the absence or paucity of the granules, so that broad, ill defined light lines mark off adjacent masses of protoplasm from one another. These lines are so related to the indentations in the deep surface of the layer, and to the arrangement of the nuclei, as to leave no doubt that they correspond in position to the cell walls which were visible during the earlier stages. The nuclei have now become more flattened than in earlier stages, and are quite eccentric in position, being much nearer the deep than the outer surface of the hypodermis. Each nucleus exhibits a single deeply staining nucleolus and a number of scattered chromatin granules.

The hypodermis has already begun to secrete the chitinous cuticula of the wing membrane (*cta. al.*), but it is as yet very thin. It becomes much thicker as the wings develop.

The next stage (Plate **3**, Fig. 12) represents the condition found in a pupa of Danais plexippus about a week before emergence. It is only a few hours older than the stage just described. It will be seen that a considerable change in the hypodermis cells has nevertheless taken place. Each sends out from its deep surface a process (*fbr. h'drm.*),

which comes in contact with the Grundmembran and fuses with it (Plate **4**, Fig. 27). Then a bundle of these processes, elongating still more, breaks through the membrane, traverses the lumen of the wing, and fuses with the Grundmembran of the opposite wall (Fig. 12, *fbr. h'drm.*). Indeed, the growth does not stop here, for the bundle of fibres pierces this second Grundmembran, and effects an attachment to the cuticula of the opposite surface of the wing (Figs. 11, 13, *fbr. h'drm.*). Very soon every hypodermis cell becomes converted into a long thin fibre stretching from the upper to the lower surface of the wing. When these fibres are stained, and cut in cross section, it is seen that the central core of the fibre remains almost colorless, while the peripheral portion, which is more highly refractive, stains deeply. As Dr. Mark suggested to me, the appearance is strikingly similar to that presented by the muscle fibres of many invertebrates, and it is therefore possible that these fibres may be contractile. It is, however, especially to be noticed, as he also remarked, that these fibres have never been observed to present the transversely striated appearance common to all the known muscles of insects. It is highly probable that they, in time, become tendonous cords, which serve to hold the two walls of the wing membrane close together during the great expansion of the wing which occurs upon emergence from the chrysalis. Schäffer ('89, p. 645, Tafel XXX. Fig. 39) observed these fibres in a cross section of the wing of a well advanced pupa, a recently emerged insect, and also in a pupa immediately before emergence. But not having had material intermediate between this and the earliest stages in the formation of the scales, his notion of the manner in which these fibres are formed is apparently inaccurate; for he seems to assume that they are merely the primitive protoplasmic processes of the hypodermis cells, such as are shown in Figure 5, *prc.* His idea is that the Grundmembran must become absorbed in some way, thus — as his Figure 39 would seem to indicate — allowing the protoplasmic processes (i. e. *prc.*, Fig. 5) of opposite surfaces of the wing to fuse together and form little pillars (each with a nucleus at *either* end), which bind the two surfaces of the wing together. Since, as I have said, he was unacquainted with any of the stages of development between those corresponding with my Figures 8 and 13, he failed to observe the gradual absorption of the protoplasmic processes (*prc.*, Fig. 5), and the subsequent formation of the hypodermal fibres (*fbr. h'drm.*, Fig. 12).

But to return to the discussion of the stage represented in Figure 12. The protoplasm which once completely filled the scales has begun to

shrink, and has become coarsely granular (Plate **3**, Fig. 12, and Plate **6**, Fig. 36). This shrinking continues, so that the protoplasm comes to occupy only a portion of the cavity of the scale, as is shown in Figure 37 (Plate **6**). The protoplasm, indeed, begins to withdraw from the scales, and as it retreats from the free end of the scale leaves behind it little chitinous pillars (*clm.*, Figs. 18, 31, 32, 37, and 41), which serve to bind the upper and lower surfaces of the scale together. This is shown in Figures 32 and 35 (Plate **6**), which represent cross sections of the scales of Danais plexippus, and in Figure 17 (Plate **3**), which shows a similarly sectioned scale of Callosamia promethea.

It is well to mention here that Spuler ('95, Tafel XXXVI. Fig. 1) has already called attention to these chitinous pillars or "Chitinbrücken," as he calls them, in the scales of Galleria mellonella.

The protoplasm continues its retraction until finally it is entirely withdrawn from the scales, and they become merely little flattened hollow chitinous sacs containing only air (*sq.*, Plate **4**, Fig. 18, and Plate **6**, Fig. 38). The scales are now completely formed, but they still lack the pigment, this being introduced later. Owing to the fact that they are hollow, and contain only air, they diffract the light, and therefore appear pure white, so that the whole wing is now in the "white stage."

It will become evident from an inspection of Figures 31, 32, 34, 35, and 17, that the striations upon the upper surface of the scale are due to a series of parallel longitudinal ridges. The under surface (i. e. the one next the wing membrane) is usually smooth, or provided with few and poorly developed ridges. This fact was first pointed out by Burgess ('80), who observed it in the scales of Danais plexippus.

A still later stage than that shown in Figure 12 is illustrated by Figure 18 (Plate **4**), which was drawn from a pupa of Danais plexippus about four days before the butterfly would have emerged. The wings at this stage are slightly ochre-yellow in color, for the protoplasm has entirely disappeared from the scales and the pigment is just beginning to form. But by far the most remarkable change is to be noticed in the nuclei of the formative cells (*cl. frm.*). (Compare Fig. 12 with Fig. 18, Plate **4**.) The chromatin has shrunk into a solid ball of deeply staining substance, and lies in the centre of the clear vesicular nuclear space. In many of the formative cells, strange to relate, the nucleus begins to divide amitotically, as is to be inferred from the conditions shown in Figures 19–22, which I believe to represent successive stages in the process of nuclear division. As a result of this process, we often

find from two to five spherical masses of chromatin within the formative cell (Fig. 18, *cl. frm.'*, and Figs. 23 and 24).

It is quite evident that these cells, having finished the formation of the scales, and being of no further use in the economy of the insect, are undergoing degeneration. The amitotic division of the nucleus is probably one of the signs of this degeneration. I have observed this amitotic division only in the case of Danais plexippus; for although I have a very complete series of sections of Callosamia promethea, I have never observed it in this insect.

It should be noted that at this stage in Danais plexippus a single leucocyte (Fig. 18, *leu'cy.*) enters each of the scales situated either upon the nervures or near the outer edges of the wings. These leucocyte-bearing scales are about twice as large as the ordinary wing scales, which are situated between the nervures; the latter, indeed, are far too small to admit the introduction of leucocytes. We shall discuss the significance of these facts under "The Development of the Pigment within the Scales," pages 224, 225.

The manner in which the scales are inserted into the wing membrane will become apparent from an inspection of Figures 30 (Plate **5**), 31 (Plate **6**), or, better still, 29 (Plate **5**). The last figure, drawn from Danais plexippus, represents a cross section (i. e. perpendicular to the trend of the nervures) of a wing that is still in the "white stage." The narrow cylindrical stalk of the scale is merely inserted into a minute close-fitting socket, which perforates the wing membrane, as was first described by Semper in 1857; it is not set into a tube, as Landois ('71, Taf. XXII. Fig. 10) imagined.

I cannot find anything resembling the curious structure described by Spuler ('95, p. 526, Taf. XXXVI. Figs. 2, 3, 4) as serving for the insertion of the scales, and called by him the "Schuppenbalg." Spuler describes this Schuppenbalg method of insertion in Galleria mellonella, Polyommatus phleas, and Lycæna alexis, and comes to the conclusion that it is general in the Lepidoptera. I believe this conclusion to be erroneous, for I am unable to substantiate it in any of the forms which I have examined, although my sections were only 6.6 μ thick, and were made in all of the three chief planes of the wing. Sometimes, however, in oblique sections (such as make an angle of 45° with the plane of the wing) one finds an appearance which might be imagined to represent the Schuppenbalg of Spuler. But the appearance is entirely due to the wing membrane being cut obliquely, the section embracing portions of two sockets. For this reason I am inclined to think that Spuler may be mistaken in his interpretation of what he saw.

It will be seen, upon inspection of Figure 29 (Plate **5**), that the folding of the wing membrane in a direction perpendicular to the trend of the nervures is very sharp. The wing membrane is, in fact, thrown into a very regular series of closely compressed folds (*cta. al.*, Fig. 29), a single scale being inserted upon the crest of each fold. It was, no doubt, the very sharpness of this folding which induced Landois ('71) to believe that the scales were actually inserted into little tubes.

When the butterfly issues from the chrysalis, these folds in the pupal wings flatten out, and it is this flattening which causes the expansion of the wings. Figures 13 and 15 (Plate **3**) are diagrammatic representations of cross and longitudinal sections, respectively, of the pupal wings; and Figures 14 and 16 are similar sections of the mature wing. It is evident that the wings after emergence undergo a great stretching and flattening. The mechanics of the operation appears to be as follows. The hæmolymph, or "blood," within the wings is under considerable pressure, and this pressure would naturally tend to enlarge the freshly emerged wing into a balloon-shaped bag; but the hypodermal fibres (*fbr. h'drm.*) hold the upper and lower walls of the wing membrane closely together, and so, instead of becoming a swollen bag, the wing becomes a thin, flat one. And thus it is that the little, thick corrugated sac-like wings of the freshly emerged insect become the large, thin flat wings of the imago. In Figure 30 (Plate **5**) we see a longitudinal section through a portion of the mature wing of Callosamia promethea, killed about two hours after emergence. The chitinous wing membrane is represented by *cta. al.*, and the contracted hypodermal fibres, which in the pupa had the form of long tapering cells, by *fbr. h'drm.* Figures 45 and 46 (Plate **6**) give the natural size of the pupal and imaginal fore wings, respectively, in Danais plexippus. The area of the wing of the imago is 8.6 times that of the pupa. Now, as the wing of the young pupa has about 60 times the area of the wing in the mature larva, it is evident, that in passing from the larval state to maturity the area of the wings increases more than 500 times.

2. The Development of the Pigment within the Scales.

In this portion of the paper we shall consider only those changes which take place within the scales themselves; these will be traced from the first appearance of the scales up to the time when the imago issues. We shall pay especial attention to those phenomena which accompany the formation of the pigment.

When the scale first appears, it is, as we have seen nothing more than a small protoplasmic protuberance of a protoplasmic cell, which soon becomes retort-shaped owing to the bending backward of the protuberance (Figs. 7 and 8, Plate **2**). Very soon, however, this little protuberance increases in size and flattens out, finally assuming the outward shape of the mature scale. Then a layer of chitin is secreted over its entire outer surface, so that the scale may now be pictured as a thin, flat chitinous bag filled with protoplasm. The chitin upon the outer surface of the scale (i. e. the surface which is away from the wing membrane) develops well marked striæ, whereas the lower surface is usually unstriated and flat (compare Figure 29, Plate **5**, and Figures 32, 35, Plate **6**). It is well known that many scales exhibit two distinct sets of striæ, a well developed longitudinal set and a much finer transverse set. The effect of the striæ is to diffract the light; they give rise to those beautiful iridescent colors, the play of which is so often to be seen upon the wings of the Lepidoptera. We see, then, that the diffraction colors of the scales are provided for long before the scales show any trace of pigment within them; but as long as the scales remain full of protoplasm, they are as transparent as glass. About ten days before emergence, in the case of the over-wintering form, however, the protoplasm which fills the scales becomes coarsely granular, and soon after this begins to shrink and to retreat toward the root of the scales (Figures 36 and 37, Plate **6**). The result is that in from three to five days the protoplasm has retreated entirely out of the scales, which are thus left with air as their only contents. In this condition they diffract the light, and appear pure white. If, however, these scales be placed in alcohol, ether, clove oil, cedar oil, or a similar reagent, the fluid fills them, and they become perfectly transparent, showing that there is no pigment present within them.

This test was devised by Dimmock ('83), who showed by means of it that the scales of many of the brilliantly colored Coleoptera are hollow, containing only air, and that the color is therefore due merely to the striæ which cover the surface. Coste ('90–'91) and Urech ('93) have shown that usually the white scales of the Lepidoptera are also merely hollow air-filled sacs, and that the white color is only an optical effect due to diffraction, not to pigment.

Those scales which are destined to be white upon the mature wing are now completely formed, and undergo no further changes. Hence, ontogenetically speaking, the white spots upon the wing are the oldest of all. Those scales which are destined to be pigmented have, however, a

different fate; for the "blood," or hæmolymph, of the chrysalis enters them, and they become completely filled with the fluid. This hæmolymph, when found in the blood sinuses of the chrysalis, is a clear amber-yellow fluid, but when taken from the pupa, and exposed to the air, it soon loses its translucency and becomes of a turbid ochre-yellow color. Some such change as this seems to come over the hæmolymph when it enters the scales, for they always exhibit a dull ochre-yellow color, which is exactly similar to that displayed by the hæmolymph a few minutes after it has been removed from the chrysalis. No matter what pigmental color the scales are ultimately destined to display, they all go through this ochre-yellow stage.

We will here digress a moment to describe the very exceptional circumstances which occur during this period in those scales that are found upon the nervures and at the outer edges of the wings in Danais plexippus. These scales are about twice as large as those that are found between the nervures. They are so large, indeed, that leucocytes may pass into them; and, as a matter of fact, a single leucocyte enters each one of them. There are two sizes of leucocytes to be found within the lumen of the pupal wings. The larger ones (Plate **6**, Figs. 48 and 52) have about twice the diameter of the smaller (Figs. 47, 49, 50, and 51). The smaller ones are by far the commoner, and they are the only ones that ever enter the scales. As soon as the leucocyte enters the scale it begins to degenerate, and finally to break down and disintegrate. Successive stages in this degeneration are shown in Plate **6**, Figs. 39, 40, 41, 42, 33, and 43.

Figure 39 (Plate **6**) is a drawing of a leucocyte that has apparently just entered the scale. The chromatin has shrunk into a small, deeply staining ball, and lies near the centre of the clear vesicular nucleus. It will be seen that the condition of its nucleus is quite different from that of the leucocytes which float free in the lumen of the wings. My reason for assuming that the leucocyte represented in Figure 39 has only recently entered the scale is, that it is the only one of many hundreds observed by me which showed any trace of chromatin within its nuclear membrane. In most of the leucocytes which one sees in the scales the nuclear membrane has disappeared and the chromatin is scattered through the whole cell (Figs. 41 and 42). I therefore conclude that the period during which the nucleus remains in an approximately normal healthy condition is very short. Disintegrating leucocytes are shown in Plate **6**, Figs. 33 and 43. It is interesting to note that the leucocytes enter only the large scales, those upon the nervures and upon the edges of the

wing, and it is remarkable that only a single leucocyte enters each of these. The fact that the leucocyte always disintegrates, is also significant, for it suggests that the hæmolymph within the scale is not in a normal or healthy condition. Furthermore, the fact that the lymph of the scale becomes turbid and of a yellow-ochre color, may perhaps be attributable to its being shut up within the scale, and thus cut off from the possibility of renewal. At first I thought that the entrance of the leucocytes into these scales might be related to the fact that the scales which lie upon the nervures and at the edges of the wings are always the last to acquire their mature colors; but this is not so, for in Callosamia promethea the scales that are found upon the nervures are not any larger than those that lie between them, all being far too small to admit the entrance of leucocytes; and yet in this case also the scales upon the nervures and at the edges of the wing are the last to acquire their mature colors. The entrance of the leucocyte seems therefore to have nothing whatever to do with the pigmentation of the scale. I believe it is due merely to the fact that the scales upon the nervures and at the edges of the wings in Danais plexippus are large enough to admit leucocytes.

But to return to the general discussion of the development of the pigment. After the wings have remained in the ochre-yellow stage for about twenty-four hours, the mature colors begin to show themselves. These mature colors always appear first within scales which are situated between the nervures. They are faint at the beginning, but gradually increase in intensity. For example, if a scale be destined to become black, it first becomes pale grayish brown, and this color gradually deepens into black. This pigment is no doubt derived from the hæmolymph within the scale, for the simple reason that there is nothing but hæomolymph within the scale at the time when it first appears. It is probably produced by chemical processes that are somewhat analogous to the clotting of the blood, for the pigment is found to be sublimed over all the surfaces of the cavity of the scale, as is shown in black in Plate **6**, Fig. 44.

It was first pointed out by Burmeister ('78), that the layer of pigment is especially thick upon the upper surface of the scale (i. e. the surface which is away from the wing membrane).

3. The probable Chemical and Physical Nature of the Pigments of Lepidoptera.

Only a beginning has, as yet, been made in the study of the nature of the pigment substances that are found within the scales of Lepidoptera. Coste ('90–'91) and Urech ('93) have carried out extensive series of experiments, which show that many of the pigment substances may be dissolved out of the scales by means of chemical reagents, giving colored solutions, and leaving the scales white or colorless. They have also shown that some of these pigments may be changed in color by the action of reagents, and then restored to their original color by the use of other reagents. For example, many reds are changed to yellow by the action of HCl or HNO_3, and may be restored to the original red color by the use of ammonia. Their researches show that reds, yellows, browns, and blacks are always due to pigments. In a few cases, greens, blues, violets, purples, and whites are also due to pigments, and not, as is usually the case, to structural conditions, such as striæ upon the scales, etc.

It is probable that the most universal pigment colors to be met with in the Lepidoptera are the yellowish-buff and brown-drab tints, and this is especially true of the nocturnal forms. The diurnal forms have almost a monopoly of the brilliant reds and yellows and the rich blacks, but it is interesting to note that yellowish-buff or brown tints are still very common upon those portions of their wings that are hidden from the light, such as the upper costal edge of the hind wing, which is usually concealed from view beneath the overlapping fore wing. Wallace ('89, p. 274) has called attention to the fact that a yellowish or buff tint is one of the commonest and most widespread colors in Lepidoptera.

Concerning the chemical nature of the pigment substances within the scales, but little has as yet been made known. Hopkins ('89, '91, '94) finds that the white pigments in the Pieridæ are due to uric acid, and also that the red and yellow pigments are due to two closely related derivatives of uric acid. These uric acid derivatives used in ornamentation are apparently confined to the Pieridæ among butterflies. For when a Pierid mimics an insect of another family, the pigments in the two cases are chemically quite distinct. This is well seen in the genera Leptalis (Pieridæ) and Mechanitis (Danaidæ).

Further, Griffiths ('92) has shown that the green pigment found in several species of Papilio, Hesperia, and Limenitis among butterflies, and

of Noctuidæ, Geometridæ, and Sphingidæ among moths, also consists of a derivative of uric acid, to which he gives the name "lepidopteric" acid, and assigns the empirical formula $C_{11}H_{10}Az_2N_8O_{10}$. By prolonged boiling in HCl it is converted into uric acid.

Urech ('91) demonstrated that in a large number of Lepidoptera the color of the urine that is voided upon emergence from the chrysalis is similar to the principal color of the scales.

Landois ('64) many years ago made a careful study of the constitution of the blood of several species of beetles and butterflies. He found that when the blood is allowed to evaporate in the air crystals separate out. He also found that the blood consists chiefly of egg albumen, but that globulin, fibrin, and iron are also present. He called attention to the fact that the freshly drawn blood of the larvæ of Lepidoptera is usually light in color, but that when it is allowed to dry in the air it generally becomes brownish or yellowish; and further, that while the colors of the bloods are different for different species, it is very remarkable that the color which is assumed by the *dried* blood is apt to be similar to the ground color of the wings of the mature insect from which the blood is drawn.

As before stated, I believe that the pigments of the scales are derived from the hæmolymph or blood of the chrysalis, and my chief reason for believing this is that I can find no evidence that there is anything but hæmolymph within the scales during the time when the pigment is formed. In considering the phenomena of pigmentation, therefore, it is important to know as much as possible about the physical and chemical properties of the hæmolymph of the pupa. Accordingly, I have devoted some time to a study of the properties of the pupal hæmolymph of the large Saturnidæ, Samia cecropia, Callosamia promethea, and Philosamia cynthia. The hæmolymph is under considerable pressure in the chrysalis, and when an incision is made near the shoulders of the wing cases it spurts out in large drops. I have made a chemical analysis of it, and find that its chief constituent is egg albumen, but that globulin and fibrin are also present. When the hæmolymph is agitated with ether, the proteid substances are coagulated, and a clear amber-yellow solution is left. This amber-yellow solution may then be decanted off from the congealed proteids. When thus isolated the proteids are slightly yellowish, but they soon dry into a drab-colored mass, very much as the hæmolymph itself does upon exposure to the air. Spectrum analysis shows that the clear amber-yellow solution owes its yellow color to xanthophyll. It will be remembered that Poulton ('85) found that the green and yellow

colors of many Lepidopterous larvæ and pupæ were due to chlorophyll and xanthophyll derived from the leaves of their food plants. The hæmolymph is acid to litmus, and I find that it actually contains a large amount of orthophosphoric acid (ammonium molybdate test). Mr. George Oenslager has kindly determined the mineral bases of the hæmolymph for me, and finds them to be iron, potassium, and sodium. The iron is present in considerable quantity.

Although the freshly obtained hæmolymph is a clear opalescent amber-yellow fluid, it soon becomes turbid upon exposure to the air, and in less than half an hour after removal from the chrysalis becomes opaque, and drab or greenish drab in color. It is interesting to note that the drab color assumed by the dried hæmolymph from the pupa of Callosamia promethea is very similar to the drab of the outer edges of the mature wings. In the case of Philosamia cynthia, also, the hæmolymph dries into a greenish drab color, which is strikingly similar to the principal color of the moth's wings. In the case of Samia cecropia, however, the hæmolymph becomes rather greener in color than the drab of the mature wings.

This curious change in color which the hæmolymph exhibits upon exposure to the air is probably not a simple process of oxidation, for it will take place in an atmosphere of hydrogen, although rather more slowly than in the air. An atmosphere of CO_2, however, practically prevents it, for after remaining for 48 hours in this gas, the hæmolymph shows only faint traces of a drab-colored clot around the edges of the liquid, which remains clear and amber-yellow in color. If the hæmolymph be sealed up air-tight in glass tubes, it will retain its clear amber-yellow color indefinitely. When the newly extracted clear amber-colored hæmolymph is heated to 54° C., it begins to congeal, and at temperatures above 63° C. it rapidly solidifies into a chrome-yellow colored mass. In this condition it will keep indefinitely, always retaining its original chrome-yellow color. In like manner congelation can be produced in hæmolymph that has become drab by exposure to the air, only in this case the congealed mass is drab, not chrome-yellow in color.

If, in accordance with my hypothesis, it be true that the colors of the mature wing are derived, by various chemical processes, from the hæmolymph of the pupa, then one ought to be able to manufacture various colors from the hæmolymph by means of chemical reagents. Also, if the color so manufactured be similar to some color upon the mature wing, it may be expected to present reactions to chemical reagents similar to those of the color on the wing. As far as my rather limited experiments

go, I find this to be the case. For example, if one treat the hæmolymph of Samia cecropia with warm concentrated HNO_3, it congeals into a deep chrome-yellow mass. If now ammonia be added in excess, it changes to a reddish-orange, which is very similar in color to the reddish-orange band that crosses the upper surface of the hind wings of the moth. Now this reddish-orange band of the moth is changed to chrome-yellow by HCl or HNO_3, and then, if ammonia be added, the original red color reappears; this alternation of red and yellow may be produced indefinitely by the successive additions of ammonia and acid. Exactly the same sequence of reactions is produced with the red pigment derived from the hæmolymph; HCl or HNO_3 causes it to become chrome-yellow, and then ammonia restores the original red color.

Another confirmatory test of a similar nature may be performed as follows. A portion of the drab-colored outer edge of the wing of Samia cecropia is treated with warm HNO_3 and the acid evaporated off at a gentle heat. By this means the pigment of the scales is changed to a deep chrome-yellow; if ammonia be then added, it becomes reddish. Very similar reactions are obtained from the hæmolymph after it has congealed, in the air, into a greenish-drab mass.

Another experiment which I have tried is the following. The freshly drawn hæmolymph from a pupa of Callosamia promethea is congealed by heat into a chrome-yellow colored mass; then HCl_3 and a small crystal of $KClO_3$ are added, and the acid is evaporated off at a gentle heat. By this means a purple mass is produced, which is changed to drab by HNO_3. The purple spots near the outer edges of the hind wing of the female moth are also changed to drab by HNO_3.

Still another confirmatory experiment may be given. The drab hæmolymph of Callosamia promethea is dissolved and changed to a sepia-brown color by warm HCl, to which a crystal of $KClO_3$ is added. An exactly similar change occurs when the drab-colored outer edges of the moth's wings are treated in a similar manner.

It is well known that the most universal colors of the more lowly organized moths are the drab-gray and yellow-drab tints; and this is what one would expect according to my hypothesis, for these are the colors that are derived from the hæmolymphs by mere exposure to the air. The brilliant yellows, reds, etc., are the result of more or less complex chemical processes, which have been slowly effected, probably through the agency of natural selection.

In connection with the phenomena of pigmentation it is interesting to note that while uric acid may easily be demonstrated by the murexide

test in the fluids of the alimentary tract of the *pupæ* of the Saturnidæ, it is never present in the hæmolymph of the *imago ;* nor can I detect it in the drab-colored pigment of the outer edges of the wings. The amount of uric acid in the fluids of the alimentary tract of the pupa increases as the pupa becomes older, so that the fluid which is voided upon emergence is always strongly impregnated with it. In the case of Pieris rapæ there is no uric acid either in the alimentary tract or hæmolymph of the larva, but it is present in the *alimentary tract* of the pupa. It seems to me probable that the uric acid of the alimentary tract of the pupa may be a product of the metabolism of the hæmolymph that is removed from the fluids of the body by the Malpighian tubules.

4. Summary of Conclusions believed to be New to Science.

1. It has been shown by Schäffer ('89), van Bemmelen ('89), Urech ('91), and Haase ('92) that the order of development of the colors upon the pupal wings of the Lepidoptera is as follows. During early pupal life the wings are as transparent as glass, but about ten days before emergence they become opaque and pure white. Soon after this a dull yellow or drab color suffuses the wings, tingeing all parts excepting those that are destined to become the white spots of the mature wing ; these always remain pure white. About twenty-four hours after the appearance of the dull yellow suffusion the mature colors begin to appear in places near the centre of the wing.

In addition to these facts, I have shown that the transparent condition of the wings corresponds to the period before the scales are formed, and to the time when they are still completely full of protoplasm. The white condition is caused by the withdrawal of the protoplasm from the scales, leaving them as little hollow bags filled with air. In this condition they diffract the light and appear pure white.

After the protoplasm has completely withdrawn from the scales, the "blood," or hæmolymph, of the pupa enters them, and soon after this the wing becomes of a uniform dull yellow or light drab color. This color is due to the fact that soon after the hæmolymph has entered the scales it changes to a dull ochre-yellow, and finally to a drab color. The same change takes place in hæmolymph which has been removed from the pupa and exposed to the air. The mature colors are due to chemical changes in the hæmolymph itself. They first appear in places *between* the nervures, never upon the nervures themselves. The last places to

acquire the mature coloration are the outer and costal edges of the wings and the nervures.

2. I here present the first satisfactory proof of the fact, that the scales are formed from modified *hypodermis* cells, and are therefore truly homologous with the hairs of Arthropods. This has been a matter of inference by Semper ('57), Landois ('71), Schäffer ('89), and many others.

3. Most of those hypodermis cells which do not contribute to the formation of the scales become elongated, stretching from one wall of the wing membrane to the opposite, with which they finally fuse; thus it is that the two walls of the wing are bound together by a great number of bundles of fibres derived from the hypodermis cells of both upper and lower walls. Dr. Mark observes that in some respects these fibres resemble the muscle fibres of many invertebrates, and he therefore suggests that at first they may be muscular, although they afterwards become tendonous in their nature.

4. The membrane of the pupal wings exhibits two sets of corrugations, or foldings, one being parallel to the trend of the nervures, and the other at right angles to it. In either cross or longitudinal sections these corrugations appear as a regular series of ridges, and a single scale arises from the crest of each ridge.

The expansion of the wings after emergence is caused by the pressure of the "blood" or hæmolymph within them, and is accompanied by a flattening out of the ridges. This pressure would naturally have the effect of distending the freshly emerged wing into a balloon-shaped bag, but the hypodermal fibres hold the upper and lower walls of the wing closely together, and so, instead of becoming a bulging sac, the wing becomes a thin flat one, which has an area more than five hundred times that of the wing pad in the mature larva.

5. Very large scales are found along the nervures and upon the outer edges of the wings in Danais plexippus. In fact, these scales are so large that, after the protoplasm has withdrawn from them, a single leucocyte enters each one. These leucocytes soon degenerate, and finally disintegrate, without, however, contributing directly to the pigmentation of the scale. The fact that the leucocytes degenerate after entering the scales indicates that the hæmolymph within the scale is not in a normal condition.

6. After the protoplasm has withdrawn, and the scales are completely formed, the nuclei of the cells which formed the scales often go through several amitotic divisions. This has been observed only in the case of Danais plexippus.

7. Landois ('64) demonstrated that the "blood," or hæmolymph, of Lepidopterous larvæ contained egg albumen, globulin, fibrin, and iron. In addition to this Poulton ('85) found that the blood of leaf-eating larvæ often contained chlorophyll and xanthophyll derived from their food plants.

I find that the hæmolymph of the pupæ of the Saturnidæ contains egg albumen, globulin, fibrin, xanthophyll, and orthophosphoric acid. Mr. George Oenslager has kindly determined for me that iron, potassium, and sodium are also present.

8. Landois ('64) pointed out the fact that the color of the dried blood of many Lepidopterous larvæ is similar to the ground color of the wings of the mature insect.

I here produce evidence tending to prove that the pigments of the scales are actually derived, by chemical processes, from the hæmolymph of the pupa. My reasons for believing this are as follows: — (1) I can find nothing but hæmolymph within the scales during the period of the formation of pigment. (2) In all Lepidoptera the first color to appear upon the pupal wings is a dull ochre-yellow, or drab, and this is also the color which is assumed by the hæmolymph when it is removed from the chrysalis and exposed to the air. (3) I have succeeded, by artificial means, in manufacturing several pigments from the hæmolymph, which are similar in color to various markings upon the wing of the mature insect; chemical reagents have the same effect upon these manufactured pigments that they do upon the similarly colored pigments of the wings.

9. Dull ochre-yellows and drabs are, phylogenetically speaking, the oldest pigmental colors in the Lepidoptera; for these are the colors that are assumed by the hæmolymph upon mere exposure to the air. The more brilliant pigmental colors, such as bright yellows, reds, greens, etc., are derived by more complex chemical processes. We find that dull ochre-yellows and drabs are at the present day the prevalent colors among the less differentiated nocturnal moths. The diurnal forms of Lepidoptera have almost a monopoly of the brilliant colorations, but even in these diurnal forms one finds that dull yellow or drab colors are still quite common upon those parts of their wings that are hidden from view.

In conclusion, it is a privilege to express my gratitude to those generous friends to whose kindness is due much that may be deemed of value in this research. To Professor Edward L. Mark I am indebted

for constant kindness, valuable advice, and criticism in reading over the proofs. Mr. Samuel Henshaw obtained for me the pupæ of Vanessa antiopa, from which it was shown that the scales arise from hypodermis cells. I am also indebted to him for many other acts of kindness. I also wish to thank Mr. George Oenslager for the analysis of the mineral bases of the hæmolymph, and Professor George L. Goodale for allowing me the use of the spectroscope apparatus of the Botanical Laboratory.

HARVARD UNIVERSITY, February, 1896.

NOTE. — The statement on page 231, which includes Schäffer among those who had *inferred* that the scales are the product of modified hypodermis cells, may seem to misrepresent that writer, for he states explicitly ('89, p. 643) that the scales are evaginations of greatly enlarged hypodermis cells: "Beide Gebilde [scales and hairs] sind, allgemein gesagt, Ausstülpungen von sich stark vergrösserenden Hypodermiszellen. Die allerdings selbstverständliche, aber bisher nicht beobachtete Abstammung der Schuppenmutterzellen von der Flügelhypodermis konnte ich sicher constatiren."

Since Mr. Mayer's absence from Cambridge makes it impossible for him to revise the proof of his paper, I take the responsibility of explaining that Schäffer's conclusion, though hardly to be called purely a matter of inference, rests upon much less satisfactory and complete evidence (he figures only one stage in the development of the scales) than that furnished by Mr. Mayer.

E. L. MARK.

May, 1896.

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EXPLANATION OF THE PLATES.

All the drawings were made, free-hand, from paraffin sections 6.6 μ thick. Unless otherwise stated, the specimens were stained upon the slide for about twenty minutes in Kleinenberg's alcoholic hæmatoxylin, and mounted in xylol balsam.

ABBREVIATIONS.

a.	anterior.
cl. frm.	formative cells of the scales.
clm.	chitinous pillars found in scales.
cta.	outer chitinous cuticula of the *larva*.
cta.'	outer chitinous cuticula of the *pupa*.
cta.''	inner cuticula membrane of pupa.
cta. al.	wing membrane.
fbr. h'drm.	hypodermal fibres of pupal wings.
h'drm.	hypodermis.
leu'cy.	leucocytes.
leu'cy.'	vacuolated leucocytes as found in the very young pupæ.
leu'cy.''	elongated spindle-shaped leucocytes.
mbr. ba.	basement membrane of the larval hypodermis.
mbr. m.	middle membrane of the larval wings.
mbr. pr.	Grundmembran of Semper.
nl.	nuclei of the stellate cells that secrete the Grundmembran.
p.	posterior.
prc.	processes of young hypodermis cells.
sq.	scale.
tb.	tubes produced from the newly formed Grundmembran.
tr.	trachea.

PLATE 1.

Figures 1–3*a* are drawn from the mature larva of *Pieris rapæ*. Figure 4, young pupa of *Samia cecropia*.

Fig. 1. Section lengthwise through the left hind wing of the mature larva of Pieris rapæ. The plane of the section is parallel to the frontal plane of the larva, i. e. perpendicular to its dorso-ventral axis.

Fig. 2. Diagrammatic reproduction of Figure 1.

Fig. 3. A portion of a cross section of the larval wing.

Fig. 3*a*. Longitudinal section through a portion of one wall of the larval wing.

Fig. 4. Longitudinal section (i. e. with the trend of the nervures) through the pupal wings of S. cecropia. The section is taken near the lower free edges of the pupal wing cases.

PLATE 2.

Figures 5, 6, *Samia cecropia*. Figures 7, 8, *Vanessa antiopa*. Figures 9, 10, *Danais plexippus*.

Fig. 5. Portion of a longitudinal section through the pupal cuticula and wing tissue. Specimen killed in January.

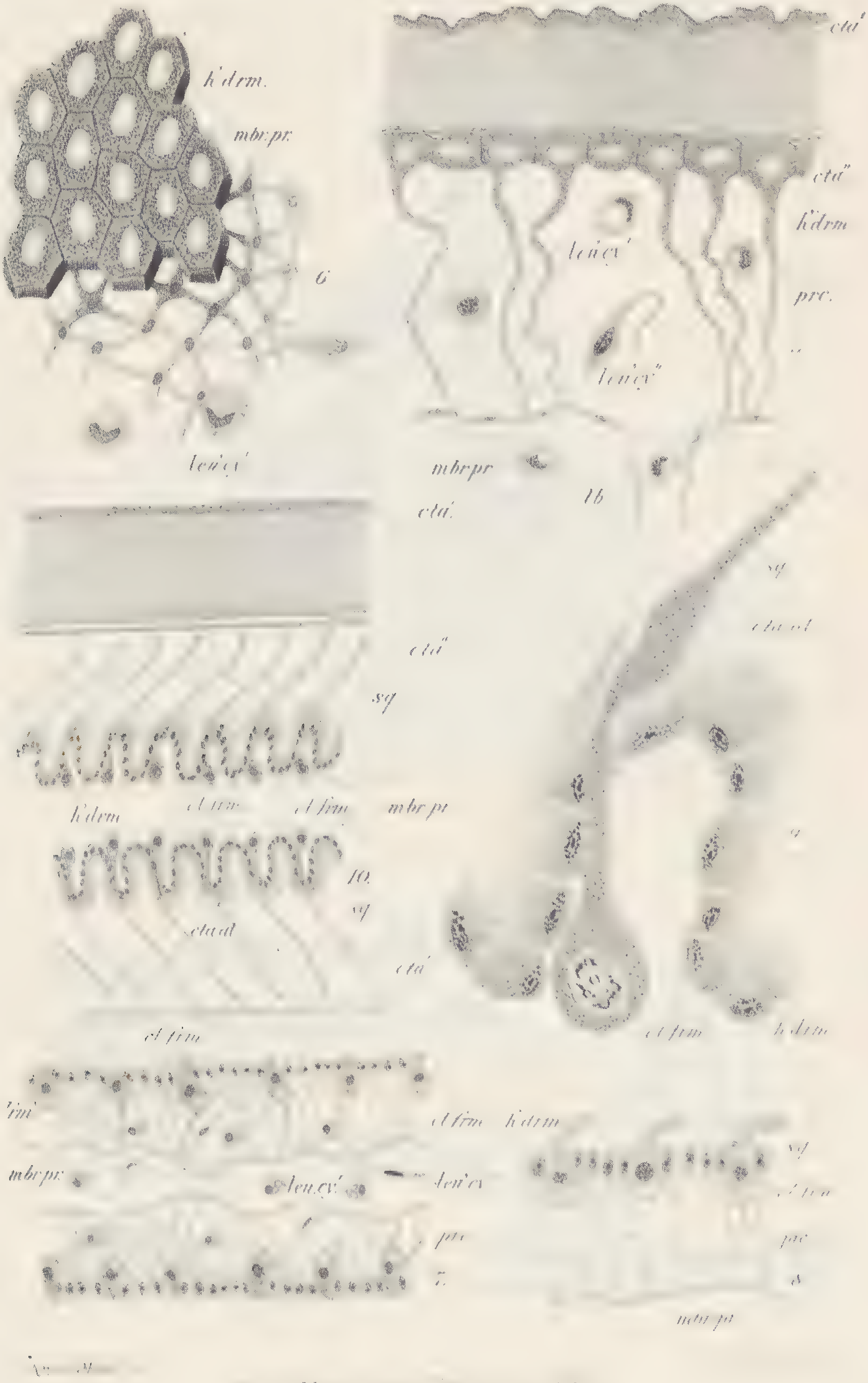
Fig. 6. Perspective view looking down upon the wing tissue of the young pupa, the cuticula having been removed.

Fig. 7. Portion of a longitudinal section through one of the young pupal wings of a summer chrysalis. Age not known.

Fig. 8. Portion of a longitudinal section through one wall only of the pupal wing of a specimen slightly older than that of Figure 7.

Fig. 9. Portion of a longitudinal section through a pupal wing about eight days before emergence.

Fig. 10. Portion of a longitudinal section through one of the pupal wings about eight days before emergence. Viewed under a low magnification.


h'drm.
mbr.pr.
6
leu.cy.'
ctá
ctá"
h'drm
leu.cy.'
prc.
leu.cy."
mbr.pr.
16
ctá.
sq.
ctá.
ctá"
sq.
h'drm
ct.fim
ct.fim
mbr.pr.
10.
sq.
ctá.d
ctá.
ct.fim
h'drm
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ct.fim
h'drm
mbr.pr.
leu.cy.'
leu.cy.
prc.
7.
sq.
prc.
8.
mbr.pr.

PLATE 3.

Figures 11–16, *Danais plexippus.* Figure 17, *Callosamia promethea.*

Fig. 11. Portion of a longitudinal section through a pupal wing about five days before emergence.

Fig. 12. Portion of a longitudinal section through a pupal wing about seven days before emergence.

Fig. 13. Diagrammatic longitudinal section of a wing to show the cross folds in the pupal wing membrane.

Fig. 14. Diagrammatic longitudinal section to show the flattening that affects the wing membrane after emergence.

Fig. 15. Diagrammatic cross section of one wall of the pupal wing to show the longitudinal folds of the wing membrane.

Fig. 16. Diagrammatic cross section of the mature wing, the longitudinal folds being obliterated.

Fig. 17. Cross section of a scale of Callosamia promethea.

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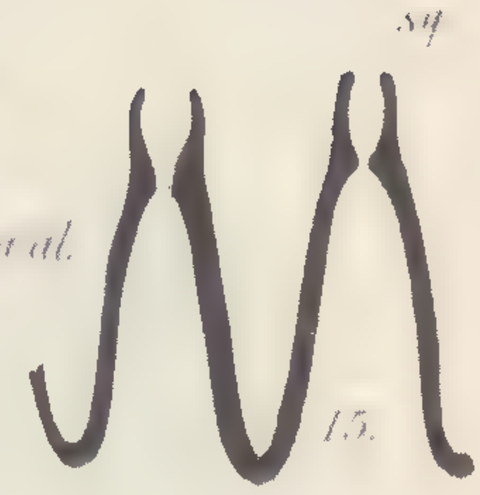
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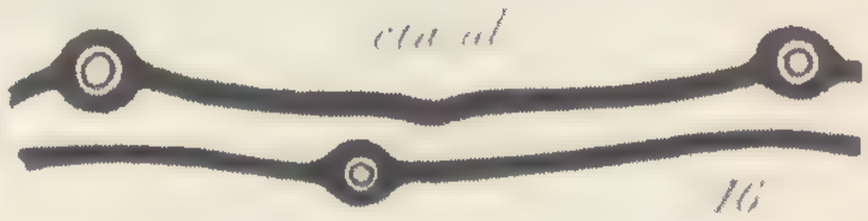
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16

PLATE 4.

Figures 18–24, 26, 27, *Danais plexippus*. Figure 25, *Pieris rapæ*.

Fig. 18. Longitudinal section of pupal wing about four days before emergence.

Figs. 19–24. Successive stages following amitotic division of the nucleus of formative cells after the completion of the scales.

Fig. 25. Portion of a cross section through the mid-dorsal region of a larva of Pieris rapæ, taken just back of the head, in the place where the cuticula splits when moults occur.

Figs. 26, 27 Edge and outer surface views, respectively, of the Grundmembran, about a week before emergence

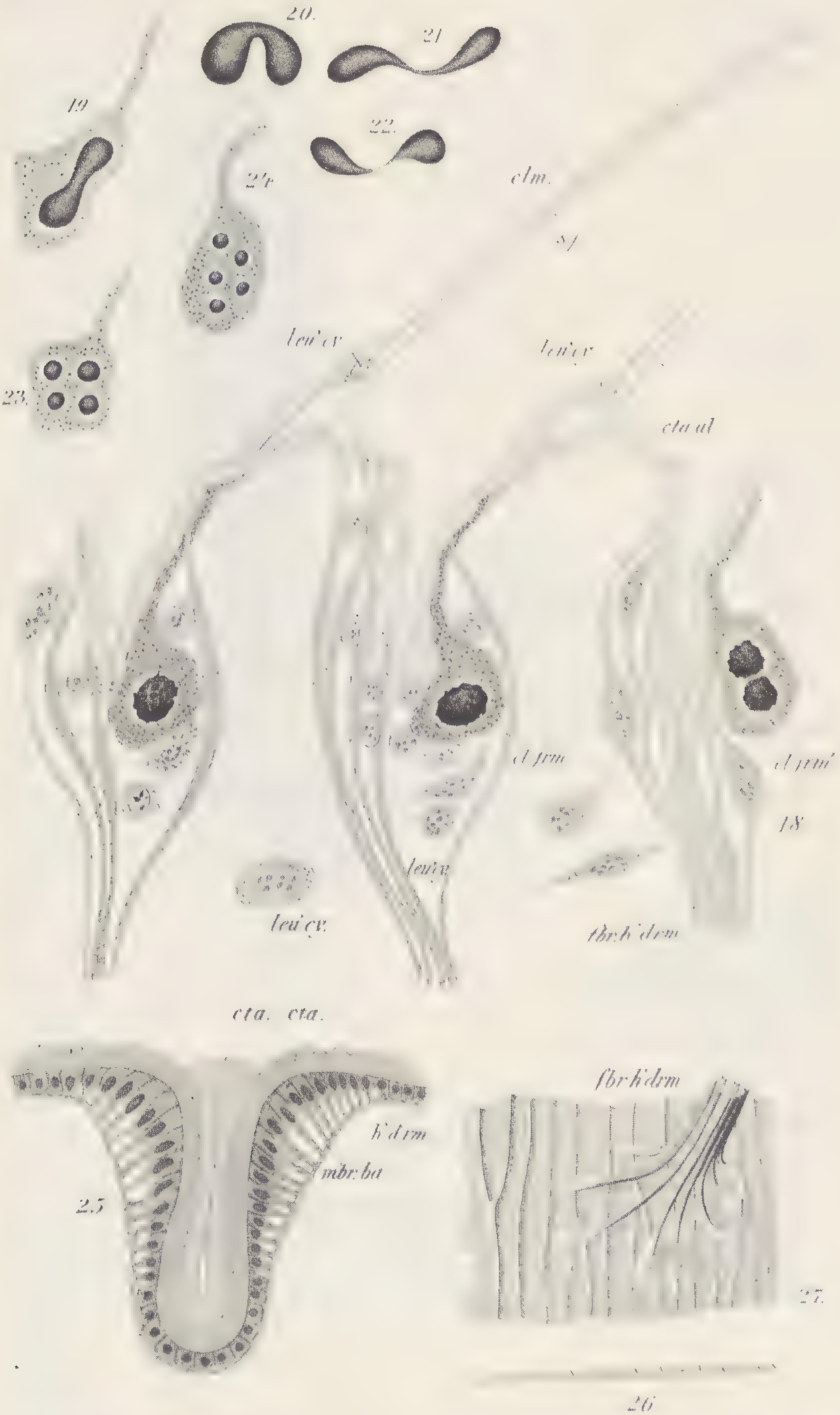

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PLATE 5.

Figures 28, 29, *Danais plexippus*. Figure 30, *Callosamia promethea*.

Fig. 28. Portion of a longitudinal section (i. e. parallel with the trend of the nervures) through the pupal wing, about eight or nine days before emergence.

Fig. 29. Portion of a cross section (i. e. perpendicular to the trend of the nervures) through the pupal wing, about six days before emergence.

Fig. 30. Portion of a longitudinal section through the mature wing about two hours after emergence.

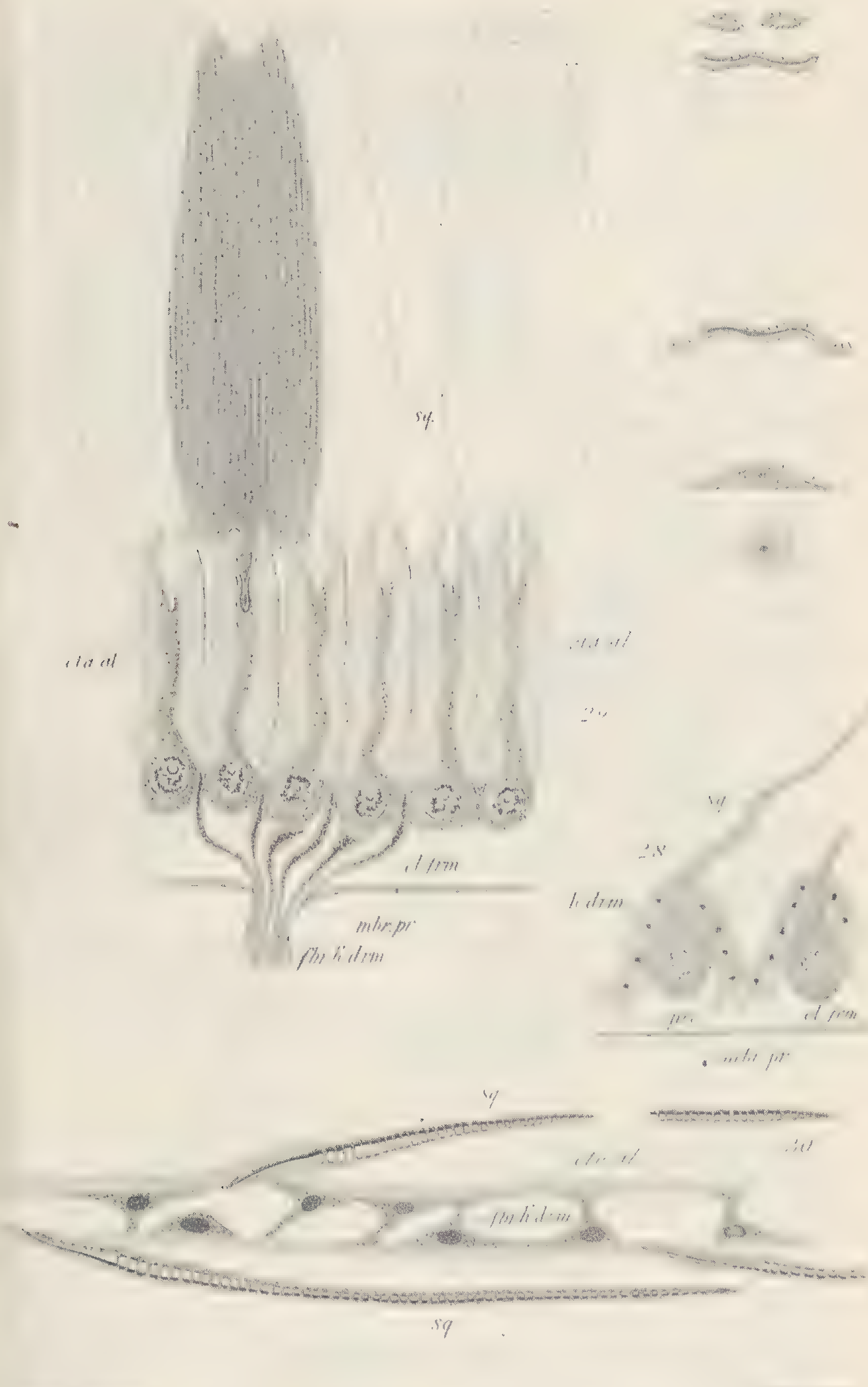
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PLATE 6.

All of the Figures are from *Danais plexippus*, and the specimens were stained with Kleinenberg's hæmatoxylin, followed by safranin.

Fig. 31. View looking down upon the upper (i. e. exposed) surface of one of the large scales situated upon the nervures. Stage about four days before emergence.

Fig. 32. Cross section of scale like that of Figure 31. Exposed surface below in the figure.

Fig. 33. Leucocyte found within the scale represented in Figure 31, about four days before emergence.

Fig. 34. View of upper surface of one of the smaller scales, such as are found between the nervures. Drawn about four days before emergence.

Fig. 35. Cross section of scale like that of Figure 34. Exposed surface below in the figure.

Fig. 36. Longitudinal section of a scale in the "transparent stage," about eight days before emergence (compare Figure 9).

Fig. 37. Longitudinal section of scale in the "white stage," about five days before emergence.

Fig. 38. Longitudinal section of scale after the withdrawal of the protoplasm, about four days before emergence.

Figs. 39–43. Longitudinal sections of scales, showing successive stages in the degeneration of the leucocyte that enters the scale.

Fig. 44. Scale just before emergence, showing disposition of the pigment represented in black.

Fig. 45. Pupal fore wing, natural size.

Fig. 46. Imaginal fore wing, natural size.

Figs. 47–52. Free leucocytes found in the lumen of the wings.

PLATE 7.

Figures 53–70, *Callosamia promethea.* Figures 71–74, *Danais plexippus.*

Fig. 53. Enlarged view of a fore wing in the "white stage."

Fig. 54. Scale from the wing represented in Figure 53 (highly magnified)

Fig. 55. Scale from light drab area of the mature wing.

Fig. 56. Under surface of hind wing of male, showing the beginning of mature coloration.

Figs. 57, 58. Under surface of fore wing of female and male respectively, to show first appearance of mature coloration.

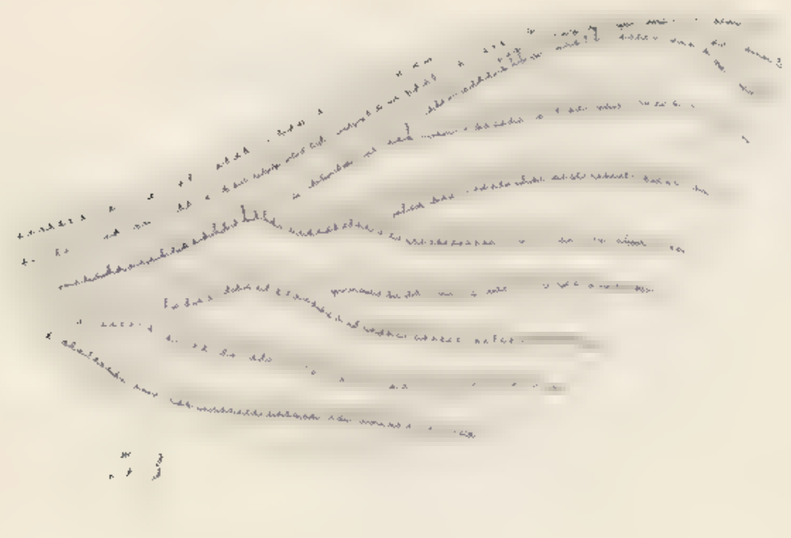
Figs. 59–64. Successive stages in the color development of upper surface of wings in male moth. (Figures 59–61, 64, of fore wing; Figures 62, 63, of hind wing.)

Fig. 65. Lower surface, hind wing, female moth.

Figs. 66–69. Successive stages in the color development of the upper surface of fore wing in female moth.

Fig. 70. Upper surface, hind wing, female moth.

Figs. 71–74. Successive stages in the color development of upper surface of fore wing in Danais plexippus.



Bulletin of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
VOL. XXIX. NO. 6.

REPORT ON THE TURBELLARIA COLLECTED BY THE MICHIGAN STATE FISH COMMISSION DURING THE SUMMERS OF 1893 AND 1894.

BY W. McM. WOODWORTH.

WITH ONE PLATE.

CAMBRIDGE, MASS., U. S. A.:
PRINTED FOR THE MUSEUM.
JUNE, 1896.

No. 6. — *Report on the Turbellaria collected by the Michigan State Fish Commission during the Summers of* 1893 *and* 1894.[1] By W. McM. Woodworth.

Through the kindness of Prof. H. B. Ward, the Turbellaria collected by the Michigan State Fish Commission during the summers of 1893 and 1894 were sent to me for study, and the present report embodies a list of the species taken; it contains descriptions of some new forms. The collections, though few in number, contribute to the Turbellarian fauna of the United States four new species, three of which have never before been described.[2] It is much to be regretted that, in the absence of any data regarding the colors and shapes of the living animals, descriptions of these new species must necessarily be based upon the appearances of alcoholic material. Since the action of killing and preserving reagents tends to destroy or bleach the pigments and alter the shapes of the animals, such descriptions make subsequent identification difficult. The bibliographical citations in the synonymy include the original authority for the species, and all references to the species in the United States, as far as known to me.

DENDROCŒLIDÆ.

Planaria simplex Wdwth.

Figure 1.

Planaria simplex Woodworth, Bull. Mich. Fish Commission, No. 8. 1896.

One specimen, "Dredge Aug. 11, 1894, off N. Y. Point, Lake Michigan." Length 4 mm., greatest diameter 1.8 mm. General shape ovate. Broadest at

[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy at Harvard College, E. L. Mark, Director, No. LXV.

[2] Recently described without figures in a preliminary abstract of this paper, published in the Bulletin of the Michigan Fish Commission, No. 8, Lansing [Mich.], 1896.

$\frac{1}{5}$ the total length from the anterior end, tapering from here to rounded posterior extremity. Anterior end rounded, set off from the rest of the body by slight lateral indentations at the level of the eyes, i. e. at about $\frac{1}{10}$ total length from the anterior end. No evidence of cephalic appendages. Mouth $\frac{1}{3}$ total length from posterior end. Eye spots elongated, crescentic, facing outward and forward at an angle of 45° to the chief axis of the worm. Intestine of the simple Triclad type; no fusion or anastomoses of the posterior stems. No indications of sexual organs; immature. Pigment located in spots of nearly uniform size, distributed uniformly over all parts of the body; no clear areas surrounding eyes or at sides of head. Color of alcoholic specimen ochre-yellow.

Planaria maculata Leidy.

Planaria maculata Leidy, Proc. Acad. Nat. Sci. Philad., Vol. III. p. 251, 1848; Vol. V. pp. 225, 289, 1852; Ann. Mag. Nat. Hist. [2], Vol. I. p. 78, 1848; The Museum, Vol. I. p. 50, 1885. Diesing, Syst. Helminth., Vol. I. p. 205, 1850; Sitzungsb. Akad. Wiss. Wien, Bd. XLIV. Abth. 1, p. 499, 1862. Stimpson, Proc. Acad. Nat. Sci. Philad., Vol. IX. p. 23, 1857. Silliman, Zeitschr. wiss. Zool., Bd. XLI. p. 70, Taf. IV., Fig. 3, 1885. Woodworth, Bull. Mich. Fish Commission, No. 8. 1896.

Dugesia maculata Girard, Nord Amerik. Monatsbericht f. Naturw. u. Heilk., Philadelphia, Bd. II. p. 3, 1851; Ann. Sci. Nat., Zool., Tom. XV. p. 181, 1893.

One specimen from New Baltimore, Lake St. Clair, Aug. 20, 1893. Seven specimens "on leaves of Nymphea, Twin Lakes, Charlevoix, Aug. 8, 1894." Four specimens from "Utricularia washings, West Twin Lakes, Charlevoix, Aug. 13, 1894." The specimens from the West Twin Lakes are much smaller than those from other stations, and three of these are mutilated at the anterior end. I have found mutilations to be very common in Pl. maculata from many different localities; they occur chiefly at the anterior end. It is possible that this species reproduces by transverse division, like Pl. subtentaculata[1] and Pl. fissipara.[2]

It is not unlikely that the form described by Girard as Pl. tigrina belongs to this species. Girard based his description on a single specimen, the anterior end of which was lacking; his description, as far as it goes, agrees with the common varieties of Pl. maculata, a species which is the commonest of our fresh water Planarians.

[1] Zacharias, O., Zeitschr. f. wiss. Zool., Bd. LXIII. p. 271, Taf. IX. Figs. 8–11. 1886.

[2] Kennel, J. v., Zool. Jahrbücher, Abth. f. Anat. u. Ontog., Bd. III. p. 468, Taf. XVIII. Figs. 4, 5, 19, 20. 1888.

*Procotyla fluviatilis Leidy.[1]

Procotyla fluviatilis Leidy, The Museum, Vol. I. p. 50, Philad., 1885. Stimpson, Proc. Acad. Nat. Sci. Philad., Vol. IX. p. 23, 1857. Diesing, Sitzungsb. Akad. Wiss. Wien, Bd. XLIV. Abth. 1, p. 517, 1862. Girard, Ann. Sci. Nat., Zool., Tom. XV. p. 164, 1893; Nord Amerik. Monatsbericht f. Naturw. u. Heilk., Philadelphia, Bd. II. p. 2, 1851. Woodworth, Bull. Mich. Fish Commission, No. 8. 1896.

Dendrocœlum superbum Girard, Proc. Bost. Soc. Nat. Hist., Vol. III. p. 265, 1851. Leidy, Proc. Acad. Nat. Sci. Philad., Vol. V. p. 288, 1852.

"Round Lake, July 9, 1894." Catalogued as "white planarian." Without doubt this is the Pl. fluviatilis of Leidy.

RHABDOCŒLIDÆ.

Mesostoma Wardii Wdwth.

Figure 2.

Mesostoma Wardii Woodworth, Bull. Mich. Fish Commission, No. 8. 1896.

Nine specimens from "algæ Aug. 20, 1893, New Baltimore," Lake St. Clair. Length 2–3 mm., greatest breadth 1–1.4 mm. Very thin and flat. Anterior end tapering, conical, rounded, marked off from the body by a slight constriction. Posterior end tapering sharply, and terminating in an acute caudal process. Pharynx large, prominent, in front part of middle third of the body. No distinct tracts of rhabditi ("Stäbchenstrassen") at anterior end. Nothing definite could be determined in regard to the sexual organs. Most of the specimens immature; the one figured, more nearly mature than the others, contains nine ova in each side of the uterus. Color of alcoholic specimens yellowish, very translucent.

Mesostoma viridatum M. Sch.

Mesostoma viridatum Max Schultze, Beiträge zur Naturg. d. Turbell., pp. 16–19, 1851. Woodworth, Bull. Mich. Fish Commission, No. 8. 1896.

Seven specimens from "Utricularia washings, West Twin Lakes, Charlevoix, Aug. 13, 1894." A note on the label reads, "Small forms green." M. viridatum is a cosmopolitan species, occurring in all continental countries of Europe, and in Scotland, Greenland, and New Zealand. This is the first record of its capture in the United States.

[1] The species marked with an asterisk were not sent to me. The accounts here given are from notes and drawings by Prof. H. B. Ward. The quotation marks refer to the labels or Prof. Ward's notes.

*Mesostoma viviparum Silliman.

Mesostoma viviparum Silliman, Zeitschr. f. wiss. Zool., Bd. XLI. p. 59, Taf. III. Figs. 1–5, 1885. Girard, Ann. Sci. Nat., Zool., Tom. XV. p. 213, 1893. Woodworth, Bull. Mich. Fish Commission, No. 8. 1896.

"Old Channel, Round Lake, Charlevoix, on algæ, July 13, 1894. Length, when swimming, 0.75–0.80 mm., breadth 0.10–0.15 mm. Rounded anteriorly, pointed at posterior end. Pharynx just anterior to centre. Each individual contained 5–7 living embryos 320 × 128 μ, which were easily set free when the parent was crushed by pressure of cover glass. Each [embryo] has at centre a prominent circular pharynx 90 μ in diameter. Color of adult deep grass-green, with lighter areas of globular shape. Zoöchlorellæ (5 μ in diameter) most abundant in front of the pharynx. Lighter areas are the embryos, in which the zoöchlorellæ are not so numerous. Color and shape of the embryos the same as the parent."

The above description differs from that of Silliman, who states that at the anterior end the animal is "etwas verschmälert und hinten abgerundet." It is difficult to account for such a discrepancy.

*Vortex armiger O. Schm.

Vortex armiger O. Schmidt, Zeitschr. f. wiss. Zool., Bd. XI. p. 25, Taf. IV. Figs. 8, 9, 1862. Silliman, Zeitschr. f. wiss. Zool., Bd. XLI. p. 67, 1885. Woodworth, Bull. Mich. Fish Commission, No. 8. 1896.
Vortex similis Girard, Ann. Sci. Nat., Zool., Tom. XV. p. 209, 1893.

One specimen, "New Baltimore, Lake St. Clair, Aug. 8, 1893. Transparent, very pale, brownish gray; intestine green. Anterior end truncated, slightly narrower than middle. Body converging toward posterior end, not [terminating] with a point but [with] an indefinite irregular bunch of digitate processes. Pharynx large, cask-shaped. Two reniform black eyes. Egg chestnut-brown. Very active."

*Vortex bilineata, sp. nov.

Vortex sp.? Woodworth, Bull. Mich. Fish Commission, No. 8. 1896.

"Round Lake, Charlevoix, dredgings from old channel, July 20, 1894. Length 0.96 mm., breadth 0.24–0.32 mm. Anterior end truncated, posterior end pointed. Pharynx dolioliform, in anterior third of body, traversed by two prominent, lateral, nearly longitudinal bands of light chocolate brown, and numerous other pale, indistinct longitudinal lines. Zoöchlorellæ in central part of the body, posterior fifth free from them, transparent brown. Egg, dark chocolate, 120 μ × 80 μ."

Microstoma lineare Oersted.

Microstoma lineare Oersted, Forsag til en ny Class. af Planariæ, etc., p. 566, Kopenhagen, 1848. Silliman, Zeitschr. f. wiss. Zool., Bd. XLI. p. 51, 1885. Woodworth, Bull. Mich. Fish Commission, No. 8. 1896.
Microstoma commune Girard, Ann. Sci. Nat., Zool., Tom. XV. p. 218, 1893.

"Old Channel, Round Lake, Charlevoix, July 13, 1894. Numerous. In chains of 2–4, solitary individuals rarer."

One broken stock of four individuals from "Utricularia washings, West Twin Lakes, Charlevoix, Aug. 13, 1894."

*Microstoma variabile Leidy.

Microstomum (*Eustomum*) *variabile* Leidy, Proc. Acad. Nat. Sci. Philad., Vol. V., p. 350, 1852. Woodworth, Bull. Mich. Fish Commission, No. 8. 1896.
Microstoma philadelphicum Graff, Monographie d. Turbell., p. 252, 1882.
Anatocelis variabilis Diesing, Sitzungsb. Akad. Wiss. Wien, Bd. XLV. Abth. 1, p. 236, 1862.

"Algæ-culture from shore, Charlevoix, July 24, 1894. One specimen, chain of four individuals."

Microstoma caudatum Leidy.

Microstomum (*Eustomum*) *caudatum* Leidy, Proc. Acad. Nat. Sci. Philad., Vol. V. p. 350, 1852. Silliman, Zeitschr. f. wiss. Zool., Bd. XLI. p. 51, Taf. IV. Figs. 4–6, 1885. Woodworth, Bull. Mich. Fish Commission, No. 8. 1896.
Anatocelis caudata Diesing, Sitzungsb. Akad. Wiss. Wien, Bd. XLV. Abth. 1, p. 236, 1862.
Eustoma caudatum Girard, Ann. Sci. Nat., Zool., Tom. XV. p. 219, 1893.

Two specimens from "Utricularia washings, West Twin Lakes, Charlevoix, Aug. 13, 1894." Anterior end not obtusely rounded, but terminating in a [illegible] rounded conical projection. Tail prominent, narrow, bearing [illegible] lumen is a stock consisting [illegible] constructed individuals. The larger specimen showed slight additional constrictions, indicative of a third generation.

Cambridge, Mass., February, 1896.

EXPLANATION OF FIGURES.

Figure 1. *Planaria simplex* WDWTH. × 15.
Figure 2. *Mesostoma Wardii* WDWTH. × 30.

W.McM. W. del. B. Mercel lith. Boston.